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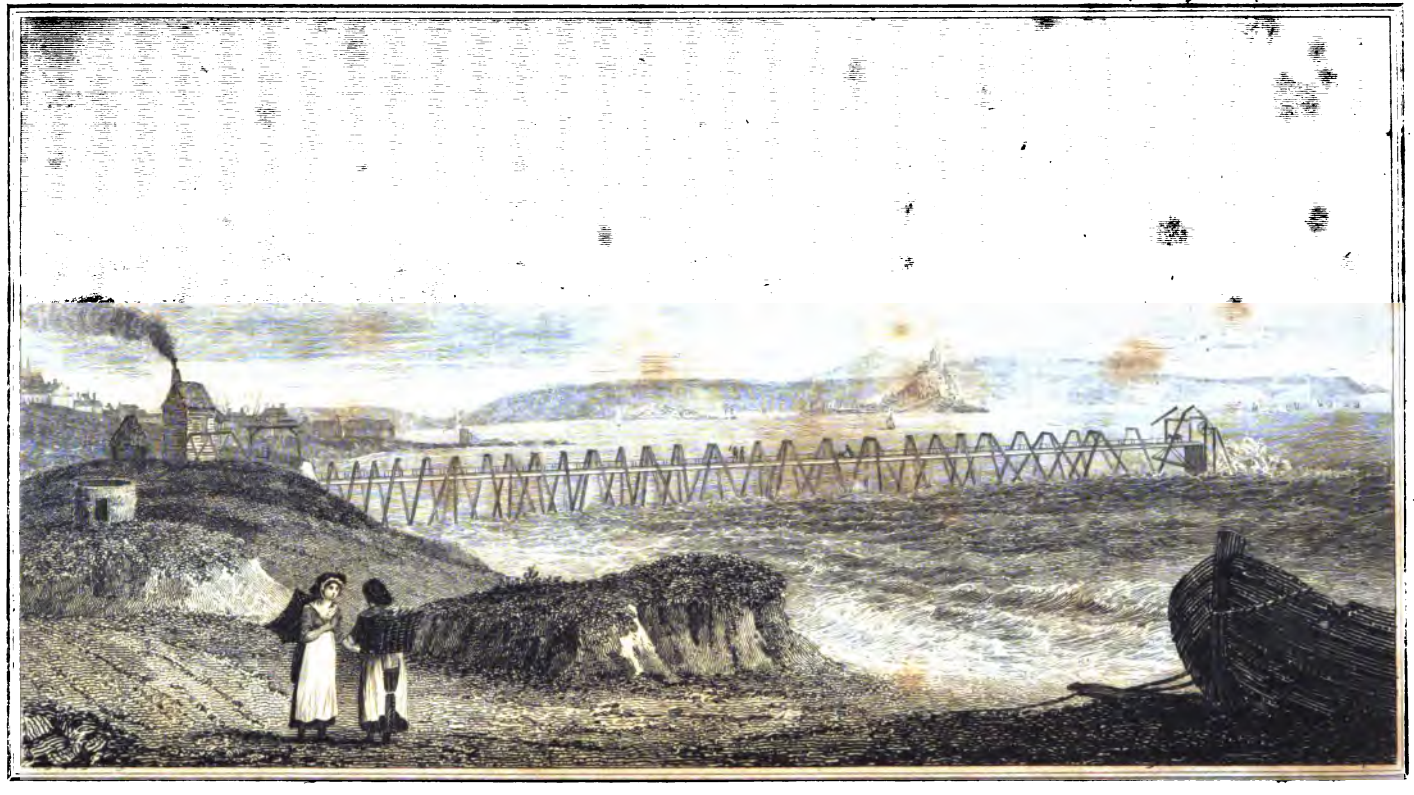

WHERRY MINE, MOUNT'S BAY, *CORNWALL.*

TRANSACTIONS

OF THE

Royal Geological Society

OF

CORNWALL.

INSTITUTED FEBRUARY 11th, 1814.

VOLUME THE FIRST.

" A knowledge of our Subterranean wealth would be the means of furnishing greater opulence to the country, than the acquisition of the mines of Mexico and Peru."

President of the Board of Agriculture.

LONDON:

PRINTED AND SOLD BY WILLIAM PHILLIPS, GEORGE YARD, LOMBARD STREET.

1818.

210573

TO HIS ROYAL HIGHNESS

The Prince Regent,

DUKE OF CORNWALL,

PATRON OF THE SOCIETY,

THIS

FIRST VOLUME OF MEMOIRS

IS INSCRIBED,

With the deepest gratitude for his August Patronage
and animating Support,

AND WITH

Sentiments of the most profound Respect, and
unalterable Attachment,

TO THE

PERSON OF HIS ROYAL HIGHNESS.

PREFACE.

THE establishment of a scientific Society for cultivating and diffusing a knowledge of Mineralogy and Geology, in a district so inexhaustibly rich in all the varied treasures of the mineral kingdom, and so singularly adapted, both from its natural structure and artificial excavations, for the examination of subterranean phenomena, must be hailed as an event of high importance, as well to the progress of geological knowledge, as to the advancement of the mining resources of the County of Cornwall; for the benefits which such an Institution is capable of imparting to our local interests, by defining and multiplying the objects of economical industry, are not less numerous and substantial than those which it will necessarily confer upon Science, by collecting, arranging, and generalising instructive facts. The want of some intelligent system of communication, some repository for the record of the new phenomena which are daily discovered in the mining districts of the county, has been long felt and often lamented; whilst

the history of the different mines offers the strongest proofs of the great necessity of soliciting, in order to obtain successful results in an art so obscure as that of mining, all the aids of reason as well as those of experience, and of combining rational theory with the routine of practice. Had such an union been always maintained, we should never have heard of the most valuable productions of our county having been thrown into the sea, nor of their having been used as materials for the repair of roads, or the construction of cottages: on the contrary, by a discipline so regulated, how many thousand tons of ore would have been gained? how many years of unprofitable, but expensive, labour saved? and how many individual adventurers would have been thus preserved from disappointment, or rescued from ruin?

The Council humbly conceive that the labours of the Society are devoted to the accomplishment of two great purposes, intimately related, and mutually subservient to each other—THE DISCOVERY OF NEW FACTS TO ENRICH SCIENCE, AND THE APPLICATION OF SCIENCE, TO IMPROVE ART. How far such reciprocal advantages may result from the exertions of this Society, the world may now form a judgment;

but in appreciating the value of its present labours, let it at least be remembered that, as yet, the Society is but in its infancy, and that, during its short progress, it has had many unforeseen obstacles to surmount, much unworthy prejudice to combat, numerous misconceptions to rectify, and great personal assistance to solicit.

The splendid and extensive series of specimens already collected, and deposited in an elegant and spacious museum, offers a most honourable and durable testimony of the zeal and talent with which this department has been conducted; whilst to the student in mineralogy, it affords a most desirable and solid system of instruction.

A Model room is attached to the Museum, for the reception of the models of new and improved machinery, and the Council beg to state, that the Society will receive with gratitude all communications upon this interesting branch of mechanical philosophy.

A list of the contributions to the Cabinet is appended to this volume, but a more distinguished notice is due to the following donors, on account of the value of their presents. To John Henry Vivian, Esq. for five hundred specimens, descriptive of the characters of

simple minerals, collected at Freyberg, under the direction of the celebrated WERNER. To WILLIAM MACLURE, Esq. of Philadelphia, for an extensive series of specimens, illustrative of the geology of the United States of America. To Mr. TREVITHICK, Engineer, for having collected in the mining districts of Peru, specimens to elucidate the hitherto unknown structure of that metalliferous country. And to ASHHURST MAJENDIE, Esq. for his numerous donations to the mineralogical as well as geological departments of the Cabinet.

In the construction of a geological map of Cornwall, the Society has made considerable progress, and the Council trust that from the zealous and united exertion of its members, its completion may be confidently anticipated.

In the successful result which has attended the efforts of the Society to prevent the loss of life by accidental explosion, the most unenlightened and prejudiced must see and acknowledge the great utility of the Institution; whilst the more liberal and accomplished members of the community, will receive with satisfaction this additional proof of the power of science to encrease the comforts of life, or to diminish the evils which so frequently attend the necessary occupations of mankind.

A

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I.—*On a recent Formation of Sandstone, occurring in various Parts of the Northern Coasts of Cornwall.*

By JOHN AYRTON PARIS, M.D., F.L.S., &c.
HONORARY MEMBER OF THE SOCIETY.

THE investigation which I have the honour to submit to the Society, is one of very extraordinary interest, as being capable of throwing considerable light upon the importance, as well as nature and extent, of some of those changes which the surface of the globe is continually undergoing in arrangement, structure, and composition; and of offering an explanation of several of the more secret phenomena which accompany them.

The decomposition and waste of hills and mountains, and the decay of the most solid parts of the earth, have excited the attention of all ages, furnishing imagery to the poet, and lessons to the moralist; but the infancy of those sciences connected with Geology has

hitherto retarded every investigation into the immediate causes of such decay, and into the nature of those hidden processes by which Nature counteracts it. Every enquiry connected with so interesting a subject will, I trust, be received by the Society with the attention its importance merits, and with that indulgence which its difficulty requires.

The *Sandstone,* which forms the subject of this paper, occurs in various parts of the Northern Coast of Cornwall, and certainly affords one of the most splendid and instructive instances of *Recent Formation* upon record; we actually detect Nature at work in changing calcareous sand into stone; and she does not refuse admittance into her manufactory, nor does she conceal with her accustomed reserve the details of the operations in which she is engaged. It does not, however, appear that any Geologist has fully availed himself of so rare an indulgence. No complete and satisfactory explanation has been hitherto afforded of this interesting formation, nor of the phenomena which attend it. At the period that Doctor Borlase wrote the Natural History of Cornwall, the science of chemistry scarcely existed: we must not, therefore, be surprised at finding that he attributed the concretion of shelly sand to the agglutinating quality of sea-water.

Recent formations, similar to that which I am about to describe, occur in various parts

of the world. Saussure informs us, that the loose sand near Messina and the Gulf of Charybdis becomes gradually so consolidated, that in a few years it serves for the purpose of millstones; which change, Saussure, as well as Borlase, attributes to the infiltration of some cementing principle from the sea. At Guadaloupe, another example is to be seen; and a splendid specimen of the stone, containing a human skeleton, the remains probably of some shipwrecked mariner, has been lately deposited in the cabinet of the British Museum, and is well known for the geological speculations which it has excited.

In describing the recent formation on the coast of Cornwall, I shall begin by offering some remarks on the natural history of the sand itself; and then, by following the steps of Nature, gradually trace her through the successive stages of the operation by which she agglutinates its particles, and completes its induration.

A very considerable portion of the Northern Coast of Cornwall is covered with a calcareous sand, consisting of minute particles of comminuted shells. That part which lies between Saint Ives and Padstow is more immediately the subject of the present enquiry; a tract which, with a few exceptions, is entirely covered with this species of sand; and which, in some places, has accumulated in quantities so great as to have formed hills of from forty

to sixty feet in elevation. A considerable area, for instance in the parishes of Gwythian and Phillack, has been thus desolated, and several churches have been inundated. In digging into these sand-hills, or upon the occasional removal of some part of them by the winds, the remains of houses may be seen; and in some places, where the church-yards have been overwhelmed, a great number of human bones may be found.

The sand is supposed to have been originally brought from the sea by hurricanes, probably at a remote period. Amongst the Arundel Papers there is mention of such an event having happened in the twelfth century; and the disproportionately high valuation of the rectory of Gwythian in the old valors, when compared with that of other parishes, which were then rated much lower, though now of very superior value, affords a probable conjecture that much land has been lost by the influx of the sand.

At present, the progress of the sand's incursion is arrested by the growth of the *arundo arenaria*;* and it would be well if the landed

* The value of this useful rush has been long known. There was an act of parliament in Scotland, so long ago as the year 1695, to prevent persons who collected this rush, (then known by the name of *starre* or *bent*) for the purpose of making mats, from plucking it up, and thereby loosening the sands: a clause to the same effect was introduced in a multifarious act of parliament in the year 1742. The operation of this clause extends generally to the North-West

proprietors of these districts were to encourage its dissemination.

The sand first appears in a slight but encreasing state of aggregation on several parts of the shore in the Bay of Saint Ives; but on approaching the Gwythian river it becomes more extensive and indurated. On the shore opposite to Godrevy Island, an immense mass of it occurs, of more than a hundred feet in length, and from twelve to twenty feet in depth, containing entire shells and fragments of clay-slate; it is singular that the whole mass assumes a striking appearance of stratification. In some places, it appears that attempts have been made to separate it, probably for the purpose of building; for several old houses in Gwythian are built of it. The rocks in the vicinity of this recent formation in the Bay of Saint Ives are *Greenstone* and *Clay-Slate,* which alternate with each other. The *Clay-Slate* is in a state of rapid decomposition, in consequence of which, large masses of the Hornblende rock have fallen in various directions, and given a singular character of picturesque rudeness to the scene: this is remarkable in the mass of rocks which constitutes Godrevy Island.

coasts of England; but such persons as claimed prescriptive right of cutting it on the sea-coasts of Cumberland, are exempted from its operation.

It is around the promontory of New Kaye that the most extensive formation of sandstone takes place. Here it may be seen in different stages of induration; from a state in which it is too friable to be detached from the rock upon which it reposes, to a hardness so considerable that it requires a very violent blow from a sledge to break it: specimens of it in these different states are deposited in the Museum of the Society. Buildings are here constructed of it; and the church of Crantock is entirely built with it. By the inhabitants, the stone is employed for various articles of domestic and agricultural use. In the sandstone in the Bay of New Kaye, I observed several holes bored, which I learnt were for the purpose of admitting cables to which the vessels were moored. I mention this circumstance to convey some idea of the indurated state of the sandstone.

In examining attentively the structure of the stone, the shelly particles may be frequently observed to be spherical, from the previous operation of water; a circumstance which throws considerable light upon the formation of *oolite*.

The geologist who had previously examined the celebrated specimen from Guadaloupe, will be struck with the great analogy which this formation bears to it; and suspecting that masses might be found containing human bones imbedded, if a diligent search were made in the vicinity of those cemeteries which have

been overwhelmed, I made an excursion with my friend Sir Christopher Hawkins; but time and patience failed us, and the discovery is reserved for some more persevering and fortunate member of the Society.

The rocks upon which the sandstone reposes are *clay-slate* and *slaty limestone,* which alternate with each other. The inclination of the beds is S.S.W., and at an angle of 40°. Upon the plane formed by the edges of these strata lies a horizontal bed of rounded pebbles, cemented together by the sandstone which is deposited immediately above them, forming a bed of from ten to twelve feet in thickness, and containing fragments of slate and entire shells, and exhibiting the same appearance of stratification as that noticed in St. Ives Bay; above this sandstone lie immense heaps of drifted sand.

But it is on the western side of the promontory of New Kaye, in Fistrel Bay, that the geologist will be most struck with the formation; for here no other rock is in sight. The cliffs, which are high, and extend for several miles, are entirely composed of it; they are occasionally intersected by veins and dykes of Breccia. In the cavities, calcareous stalactites of rude appearance, opaque, and of a grey colour, hang suspended. The beach is covered with disjointed fragments, which have been detached from the cliff above, many of which weigh two or three tons.

If we extend our observations towards Padstow, we shall find some very instructive phenomena in Permiscen Bay, to which I shall hereafter have occasion to allude.

Such then is the nature and situation of this most interesting formation of recent sandstone. In the next place, we have to enquire into the causes which have operated in thus consolidating the sand, and into the peculiar circumstances under which this operation has been conducted.

It will appear that there are three distinct modes by which the lapidification of calcareous sand may be effected, and that the present formation is capable of affording characteristic examples of each of them.

It is my intention to consider these different principles separately: the subject is full of importance, and may, by disclosing the operations of nature, lead to improvements in art. By discovering the phenomena which attend the formation of rocks, we may be led to the improvement of the different cements in present use, or to the invention of others which have never yet been employed.

The three species of cementing matter to which I allude, are all deposited from water in which they are either held in chemical solution or mechanical suspension; the water having derived them from the substances which it has percolated: thus, the first species is obtained.

I.—*By the percolation of water through a hill of calcareous sand, by which it becomes impregnated with Carbonate of Lime.*

Carbonate of lime, without an excess of carbonic acid, is very sparingly soluble; but it is the very minute quantity of the substance, held dissolved in a large quantity of water, which renders its texture so compact and dense when precipitated, and its cementing powers so considerable; for it may be stated as a general principle, *that the density and compactness of a precipitate will vary, in an inverse ratio, with the rapidity with which it is deposited.* Thus *Calcareous Tufa,* which is rapidly deposited from warm springs, is light and spongy in its texture; whereas *Travertine Marble,* being slowly precipitated from the waters of Tivoli, assumes a solid compact form. A familiar illustration of the dense texture and cementing property of precipitates, when they are slowly deposited, is presented to us in the instances of the obstinate adhesion of calcareous incrustations to the interior surfaces of water-decanters.

A very dense and compact limestone is now forming, from slow deposition, in the vast lake of Erie, in consequence of the evaporation of its waters, that are derived from rivers which have flowed through extensive countries of limestone: this formation may be seen on the sides of the lake; and, during frosts, large frag-

ments of it, attached to blocks of ice, may be observed floating on its surface. When the Falls of Niagara are destroyed, which in the common course of geological changes must take place, this immense lake will be drained, and future geologists may be then engaged in speculating upon its limestone, as we are now with a similar one which lines the great basin of the Mississippi, and which probably derived its origin from the same cause.

I have dwelt upon this subject to shew the solubility of carbonate of lime, and at the same time to prove, that when it is precipitated by slow evaporation, it assumes a highly compact texture, and possesses considerable power of lapidification. The application of these views to the present subject is obvious :—the carbonate of lime, derived from the solution of a portion of the shells through which the water flows, affords the cement; whilst the slowness with which it is again precipitated, accounts for the extreme hardness

* At the request of my friend Mr. Whidbey, the intelligent director of the Plymouth Breakwater, I have lately examined the water which is to supply the British navy. A reservoir has been formed capable of holding sixteen thousand tons of water. The water, which is constantly running into it, is extremely pure, containing only a very minute proportion of carbonate of lime, which it must have acquired during its percolation through the transition limestone of that district. The effect of this will be the deposition of a stratum similar to that in Lake Erie, and consequently it will give a permanent security to the reservoir, and effectually prevent any leaking.

and compact texture of the sandstone; striking examples of this fact may be seen in Permiscen Bay.* Had the cementing principle been held in solution by an excess of acid, it would have been deposited in a larger quantity, as well as with greater celerity, and the sandstone would probably, under such circumstances, have been spongy, friable, and scarcely indurated.

Let us proceed to the second source whence a lapidific principle may be obtained.

II.—*The percolation of water through strata containing Pyritical Substances, by which it becomes impregnated with Sulphuric Salts.*

I was led to suspect that the cementing principle might occasionally be a *sulphate* of lime, from discovering in a specimen of the sandstone small transparent crystals of selenite, disseminated through its substance. The loose sands, which are said to be found lapidified in volcanic districts, may possibly derive their principle of solidification from the action of sulphuric

* It is a curious circumstance that water thus impregnated with carbonate of lime, from its infiltration through shelly sand, should from time immemorial have enjoyed a reputation in the neighbourhood for curing diseases. I examined the waters of Holywell, so called from its supposed virtues, and those of Permiscen Bay, equally extolled for their medicinal qualities, supposing that I might possibly detect in them the presence of iron: but I found only *carbonate of lime*, in minute quantities.

waters; but I have not had any opportunity of ascertaining the fact by experiment. The sulphatization of pyrites in the presence of calcareous matter, is a universal source of gypsum: the circumstances under which the elements of these substances combine, and the various chemical changes which accompany them, I consider as amongst the most interesting facts which have been disclosed by the researches of the mineralogist.

The granular gypsum from the Falls of Niagara, which Dr. Kidd describes as being "as white as snow," owes its origin to a natural process of this description. I am informed by Mr. Maclure of Philadelphia, who has visited the spot, that it is formed in consequence of the action of water upon decomposing slate which contains numerous veins of *carbonate of lime* and *sulphuret of iron*.

I have in my possession a series of incrustations which were taken out of the boilers of several steam-engines;* one of them presents an admirable instance of the formation of sulphate of lime, and its surface is beautifully studded with well defined crystals of selenite; the water which supplied the boiler, and from the evaporation of which this substance was deposited, was drawn from the depths of a mine,

* An account of these specimens is recorded in the Minutes of the Society, and published amongst the Scientific Notices at the end of this Volume.

the country of which I ascertained to be clay-slate, intersected with veins of *pyrites*, and small runners of *carbonate of lime*.

There would seem to be a singular disposition in all the combinations of iron to pass successively through a series of complicated arrangements; a property which has evidently been bestowed upon them in order more effectually to ensure the general distribution of an element so essential to animal and vegetable existence, and so active in producing many important changes in the mineral œconomy of the globe; some of which will form matter for consideration under our third and last, but most general, principle of lapidification, viz.

III. *The percolation of water through decomposing slate, or any other ferruginous strata; by which it becomes impregnated with iron, alumina, and other mineral matter.*

The infiltration of water which has previously traversed a country of decomposing slate, or of other strata, into loose sand, is a very common and extensive cause of lapidification. At Pendeen cove, in the parish of St. Just, a stratum of granitic sand is at this time gradually hardening into sandstone, or granitic *breccia*, in consequence of such an infiltration; strata of pebbles may be also seen agglutinated from the same cause.

The sandstone upon which the town and castle of Nottingham are situated, is evidently of recent formation, owing its aggregation to the presence of iron and clay. The calcareous sand may be seen in a state of encreasing induration from the same cause, in numerous parts of the coast of Cornwall, especially in the cliff of Saint Ives Bay, about a mile north of the estuary at Hayle; where a stream of water is slowly percolating decomposing slate, and dripping upon the loose sand on the beach, which is gradually becoming indurated in the direction in which the water diffuses itself. It has been long known that in the induration of mineral substances, iron acts a very important part, and we shall also find in the course of the present enquiry, that this element is no less active in effecting their decomposition and decay.

In alluding to its cementing property, the most superficial observer must have noticed the concretions which constantly appear on the beach around a rusty nail, or any fragment of iron; and the mineralogist is well acquainted with the proofs which Mr. Kirwan has collected in support of the fact. Dr. Fothergill also states, that stones already formed may be still farther indurated by the infiltration of slightly oxidized iron. Thus having repeatedly washed pieces of Portland Stone with water impregnated with iron, he found them in a few

years to have gained such a degree of hardness, as to yield a metallic sound when struck, and to resist the impression of any ordinary tool: this result also clearly explains the cause of the superior hardness of coloured to white marbles. It is unnecessary to multiply examples. It cannot be denied that iron, in a certain stage of oxidation, possesses the property of cementing and indurating the particles of bodies with which it may be combined; nor is it less certain that this operation is limited, and that iron not only ceases to produce such an effect by combining with more oxygen, but that, by such a change, it acquires an opposite property, and becomes the immediate and active cause of decomposing the very rock which it formerly consolidated. One instance may suffice to illustrate this truth. The sandy soil in the neighbourhood of Ommersley, Halesowen, and many other parts of Worcestershire and Shropshire, is derived from the *Sandstone* of the Midland Counties, the disintegration of which has been effected by the peroxidation of its iron, as is shewn both by its red hue, and by the green colour which it imparts to the glass of Stourbridge, of which it constitutes the principal ingredient. The Count de Bournon appears disposed to believe that the decomposition of primitive rocks has been the only source from which the iron has been derived, that is now so universally spread over the

surface of the earth.* We recognise in these facts the operation of a most beautiful and important law; we learn that the most opposite effects are produced by the modification of but one principle, and that FORMATION and DECOMPOSITION are not, as the ignorant suppose, the beginning and end of material existence; but terms expressive of well regulated operations, which extend through ages of endless duration, maintaining and perpetuating the harmony, beauty, and integrity of the universe. The ruin therefore of our hills, and the various catastrophes which the surface of our earth continually undergoes, must be no longer considered as the awful type of frailty and decay, or as preludes to the more fearful changes which the superstitious observer is ever ready to anticipate; but they must be regarded as wise provisions to ensure on the

* Some French Philosophers have imagined that iron owes its origin to decayed plants and animals. I would take this opportunity to observe, that vegetables appear to possess the power of deoxidizing the compounds of iron, and thereby of rendering them soluble in their juices: this apparently explains the conversion of vegetable matter into pyrites, by the infiltration of chalybeate salts. May not this be one of the means employed by nature for rendering iron again useful in the scheme of creation, by restoring that portion into circulation which has become, during its agency, insoluble and inert by peroxidation. That animal matter possesses similar powers has been shewn by Mr. Pepys,—(see Transactions of the Geological Society of London.)

surface of the globe that circle of changes so essential to animal and vegetable existence.

> " By ceaseless action, all that is, subsists.
> Constant rotation of th' unwearied wheel,
> That Nature rides upon, maintains her health,
> Her beauty, her fertility.—She dreads
> An instant pause, and lives but while she moves.
> Its own revolvency upholds the world."

Since this paper was read before the Society, my friend, Mr. Boase, has enabled me to add another striking and beautiful illustration of the peculiar views which I have endeavoured to maintain. " I have," says he, " lately visited the Islands of Scilly; no where is the operation of the elements, in decomposing rocks, more visible and striking; indeed so rapid is the progress of disintegration, that unless some regenerating operation be instituted by nature, this land of rocks will, at a period which in the language of Geology may be styled not very remote, be a range of sand banks. Struck with such an appearance, and bearing in my recollection the principles developed in your memoir upon the recent Sandstone formation, lately read before the Society, I was sanguine in the hope of discovering in these islands, an additional testimony of their truth. My search has been rewarded by complete success; a process similar to the one you have described, may be detected in its progress, on an extensive scale, in the Island of St. Mary,

behind the quay, and between the front of the Garrison Hill and Rat Island. In these places the granitic sand is becoming indurated by the slow infiltration of water holding iron in solution, which appears to be derived from the decomposing hills above it."

Many instances of "*regenerated granite,*" as it has been termed, similar to that which Mr. Boase has described as occurring in the island of St. Mary, have been placed upon record. Pallas is of opinion that all stratified granite is formed from the decomposed grains of the primitive mass. Dr. MacCulloch has also observed that the whole of the southern and western parts of the island of Alderney are composed of a *grit,* which is evidently an aggregate, derived from the debris of granite.

Lasius found granitic sand, employed in filling a dyke in the Elbe, hardened to such a degree in the space of sixty years, as to present a solid mass, scarcely distinguishable from primitive granite; he also found that where both were in contact, they were with difficulty separated by a blow. Saussure found it in the fissures of Gneiss. Lavoisier also discovered, near the mountain of Hypolite, two beds of indurated granite, or, as he calls it, *true* granite, alternating with two beds of granitic sand that lay over each: this can have been no other than *regenerated* granite, formed by infiltration from the superior granitic sand.

That the harmony of the universe is maintained by the reciprocal operation of the power of creation and of destruction, was a favourite opinion of the ancient philosophers, and we find constant allusions to it in their writings.

> "Sic omnia Fatis
> In pejus ruere ac retro sublapsa referi."

Nor have they omitted to perpetuate such an idea by symbolical images; we recognise it in the emblem of a Lyre supported by a Bull and Lion; thus expressing that Apollo was worshipped under the double character of the Creator and Destroyer.

It was, however, reserved for the researches of modern science to bring to light the nature of those operations, by which such a harmony was preserved. The views which have been offered in this memoir seem to afford some clue to the investigation. To discover order and intelligence in scenes of apparent wildness and confusion, is the pleasing task of the geological enquirer; in contemplating the circumstances connected with the formation of the sandstone, a most beautiful and unexpected demonstration of design is afforded; like the mariner cast upon an unknown shore, we discover the traces of a footstep upon the sand, and may exclaim with rapture—'A God dwelleth here.'

II.—*An Account of some Granite Veins at Porth Just, near Cape Cornwall.*

By JOHN DAVY, M.D., F.R.S., &c.
MEMBER OF THE SOCIETY.

THE Granitic veins about to be described are situated at Porth Just, near Cape Cornwall, and below the tin-mine called *The Little Bounds*.

A brief and very general account of the adjoining rocks will first be given, which may be useful, preparatory to the description of any minute phenomena.

Towards the South, the cliffs are composed of granite; and, towards the North, of the *Killas* of our miners, or of what appears to me to be *Greywacké Slate*. The granitic and schistose rocks are separated by a large vein of *metalliferous quartz* (the *lode* of the mine above mentioned); which, besides oxide of tin, for which it is worked, contains some native copper, different oxides of iron, and a variety of

minerals. The granite, as is the case in most mountain-masses, varies considerably in appearance and composition in different places. The mica in some places is black, in others greenish, and in some white. The felspar is either white or reddish, and presents either small indistinct crystals, or large and regular ones. Neither is the difference confined to the colour and size of the constituent parts; the proportion of each is not uniformly the same, sometimes one ingredient, sometimes another preponderates; besides felspar, quartz, and mica, other substances may be observed in different places, as crystals of schorl or tourmaline, crystals of the oxide of tin, iron pyrites, and probably many other minerals might be found on more minute examination. In most places, the granite is traversed by veins of quartz, which in general are of a very small size, and run in various directions. They appear to belong to that class of veins commonly considered contemporaneous, and they constitute the matrix of the ores just mentioned. The killas or greywacké slate presents also some variety; it varies in hardness, in the proportion of mica and quartz it contains, and also in the proportion of the other ingredients; it varies too in the fineness and coarseness of its lamellar structure, and in the veins by which it is traversed. In most places, it resembles the *killas* that occurs at St. Michael's Mount; but no remarkable induration

of its substance is to be observed where it approaches the granite, or where the granitic veins pass. It dips towards the North, so that the upper ends of the strata are elevated towards the South, but at an angle which is less than 45°. In it quartz greatly abounds, and chiefly in the form of layers, which appear to be contemporaneous with the rock in which they exist. This opinion is drawn from the following circumstances: the layers are mostly horizontal in their general direction, in many places tortuous, never apparently connected with any particular veins, and they are very irregular in size and form: in this killas too are situated the veins which have a granitic appearance, and of which a description may be now given.

The number of these veins is considerable; they were not counted, but probably exceed fifty; their size greatly varies; the largest vein is more than five feet thick, and the smallest observed was not more than one-tenth of an inch in diameter. They run in different directions; some about W. N.W. and E.S.E., some about E. and W., and some nearly opposite, as N. and S., and consequently they occasionally intersect each other. In one instance of intersection, the disjointed parts of the vein running about N. and S. were *heaved* (as the miners in their expressive language term the fact,) about half an inch out of the course of the vein.

The position of most of these veins is perpendicular, or nearly so; this position to a considerable extent is well demonstrated in one vein by a perpendicular section of the cliff. In some places, the veins are observed to bend out of the perpendicular, and to approach more or less the horizontal line; in composition, and of course in general appearance, they differ very much.

Some of the veins, and one vein especially, very much resembles the most perfect crystallized granite, consisting distinctly of felspar, quartz, and mica. This vein is not above an inch broad in the widest part, and in the narrowest, just before it disappears, it does not exceed a line: it occurs near the lode. Some of these veins abound in quartz, and have very much the appearance of a fine, compact, granular, siliceous sandstone: of this description is the largest vein, which is more than 5 feet thick. It has a porphyritic appearance from the reddish crystals of felspar which it encloses; and it contains besides some crystals of tourmaline and a little mica. In some places, this vein is of a dark grey colour, and in others of a light reddish brown; it every where presents a very fractured appearance, and conveys the idea of fragments very closely compacted together; it runs about E. and W. and overlies towards the South. Some abound in felspar, and resemble veins of compact felspar rather than granite.

No where could any connexion be traced between the veins and the great neighbouring granitic mass; and most of the veins, even the smallest, appeared insulated.

Here it may be remarked that no small masses of granite were observed included in the *killas*, or of the killas in the great mass of granite; but small portions of killas, similar to the contiguous rock, were not uncommon occurrences in the granitic veins.

After this brief description, the theoretical bearings of the phenomena are the next subject for consideration. The highly inclined position of the veins, their crystalline nature, the neighbouring granite, seem circumstances favourable to the Huttonian system—that they were projected from below, and that they emanated from the adjoining granite. On the contrary, the variety of their composition, and the little resemblance which many of them have to the neighbouring granite, are circumstances unfavourable to their identity of origin. The existence of felspar, quartz, and mica, in *killas*; the existence of each of these subtances (as was observed at Porth Just) in a crystallized state; the occurrence of killas abounding in felspar; the occurrence of horizontal veins of quartz in the killas, somewhat resembling the granitic veins, and containing a little felspar and mica, as is frequently the case; and, lastly, the existence of true granite in such a vein, are circumstances favourable to the idea that the

veins called granitic in this paper are *contemporaneous* with the rock enclosing them. The last-mentioned circumstance, the existence of true granite in a vein of quartz, is particularly agreeable to such a notion; and, as I believe it to be a new occurrence, a more minute description of the phenomenon may be useful, to give due weight to the argument. The vein of quartz in which it was observed, is very near the lode of "Little Bounds," in a rock of killas on the sea-shore: it is 3 or 4 inches broad, has numerous branches, contains very good crystals of felspar, and some coarse quartz crystals, with plates of mica; and in one place, by a happy mixture of these different substances, a compound is formed, which has very much the appearance of common granite, and seems only to differ from it in containing more mica and felspar than usual, and in being softer and less compact.

Such are a few of the arguments that may be brought forward on each side of the question: none of them are decisive; and they merely tend to shew that further enquiry is necessary before the phenomena of granitic veins can be satisfactorily explained, or reconciled to any system. Such an enquiry, it is greatly to be hoped, will be prosecuted in Cornwall, where so many circumstances are peculiarly favourable to the investigation; where so many veins of the kind exist, have already

attracted the attention of strangers, and have become the subject of interesting discussion.

I cannot conclude this paper without requesting the attention of the Society to another spot where granitic veins occur, and in a peculiarly interesting form. *Pendeen Cove* is the place alluded to: here the granite veins are numerous and large; and, what is particularly worthy of notice, they may here be seen emanating from a great mass of granite, and passing into the killas by which the granite is covered.

III.—*Notes on the Coast West of Penzance, and on the structure of the Scilly Islands.*

By ASHHURST MAJENDIE, Esq. M.G.S.L.
HON. MEMBER OF THE SOCIETY.

THE granitic veins which traverse the Killas of Cornwall, have been often noticed as among the most interesting geological phenomena of this district. I beg to call the attention of the Society to one remarkable instance. A little south of the pier at the village of Mousehole, and about three miles S.W. from Penzance, the clay slate ceases and the granite commences, forming a promontory which runs out in a southern direction from the central ridge. The slate is of a grey colour: it is in strata nearly horizontal, but having a slight dip to the east; it increases in hardness near the junction. The granite, which is generally coarse and porphyritic from the large imbedded crystals of felspar, becomes here of a finer grain, with black mica, and light flesh-red felspar. On the north it laps over the schistus.

At this spot numerous granite veins, varying in width from about a foot to less than an inch, pass through the slate; the two principal veins proceed nearly east from the hill above, for more than fifty yards, until they are lost in the sea. One of these, not far from its first appearance, is divided and *heaved* several feet by a cross vein, consisting of quartz intermingled with slate; fragments of slate appear also in the granite veins. The most remarkable vein, after proceeding vertically for some distance, suddenly forms an angle, and continues in a direction nearly horizontal, having slate above and below. Now one of the theories advanced on this subject, supposes that ridges of granite were left, and the slate subsequently deposited on the sides, giving the appearance of veins: the facts I have stated seem utterly irreconcileable with such an idea, and seem only explicable on the notion of a formation of granite, secondary to, or contemporaneous with, the slate.

Slate occurs again beyond Lamorna Cove, and then granite, which forms the most western promontory at the Land's End, and continues nearly to Cape Cornwall. By descending to the sands on the west side of the Loggan Rock at low water, the porphyritic granite may be observed in great perfection; the surface being polished by the action of the waves, the form of the felspar appears distinct; here also are numerous granite veins which are probably

contemporaneous, being tortuous in their course, sometimes horizontal, and the walls indistinct and irregular: there are also many concretions of finer grained granite and schorl rock. These, which, on a slight view, might be taken for fragments, appear to be contemporaneous also; being often penetrated by large crystals of felspar proceeding from the granite mass.

Near Porth Just, a vein is worked for tin; and having been informed by Mr. Chinhalls, the agent, that there was a continual formation of stalactites in that vein, Dr. Davy and myself descended to a part of the mine under the sea, which had been closed for two years, and from which all the stalactites had been removed. We here found numerous stalactites of oxide of iron, some eighteen inches in length, of the diameter of about half an inch, and hollow. The water which percolates is salt to the taste.

The site of the 'Crown' Engine at Botallack, is a spot of great interest, as well from the curious nature of the rocks, as their singularly wild and picturesque appearance; the steam engine is on a rock at the foot of an immense precipice, over which the waves break in stormy weather, and the ore is partly drawn up the face of the precipice and partly carried by mules, by a path worked out on the brink. A vein of Garnet Rock runs in the slate, accompanied by thallite. The lowest rock is a compound of garnet, tourmaline, and axinite.

The cliff of Trewellard, at a short distance, contains the latter substance most abundantly, both amorphous and crystallized. It may be worthy of consideration how far the occurrence of garnet and axinite, which are usually found in primitive rocks, bears on the question of the antiquity of the killas of Cornwall, in which they occur.

The Scilly Islands consist almost entirely of granite, resembling that of the chain which runs through Devonshire and Cornwall, containing also veins of red granite. A beautiful variety occurs at the Lizard Point, Trescow Island, in which the felspar is of a pure white, and the mica crystallized in the primitive form. In the same island is a remarkable cavern, in the center of which is a pool of fresh water: the dimensions may be seen in the report of Mr. Tucker, proposing the formation of a break-water.

There is one part of the Island of St. Mary which I much wish should be visited by some geologist of eminence, as there appears, in my opinion, an undoubted case of stratified granite. It is at the eastern part of St. Mary's, near a small brook, where are to be found beds of a porphyry, consisting of a base of felspar, with crystals of quartz and felspar. These beds are stratified; they pass by slow gradations into true granite, which also is stratified, dipping north-west at an angle of about 45°.

A small quantity of tin was raised in St. Mary's about 20 years ago, but I saw nothing to render it probable that any large workings had taken place in more ancient times. The granite of Scilly is very liable to decomposition; this seems to be the cause which has formed the Druidical rock basins of some zealous antiquaries; if there be any doubt on this subject, it may be satisfied by observing, that many of these basins are situated vertically, according to the direction in which the storm proceeded. These islands are now undergoing that diminution which has already reduced them so much. At no great length of time, St. Mary's will probably be divided by the sea, and a channel formed through the low land, between the New Town and the S. E. side of the garrison. This might be prevented by throwing down masses of granite from a neighbouring hill to form a barrier against the sea: the object may be worthy of attention, as the sea in winter, with a high tide, has been known to pass over this land, and the effect of its forcing a channel there would be to divide the garrison from the rest of the island.

IV.—*A Sketch of the Geology of the Lizard District.*

By ASHHURST MAJENDIE, M. G. S. L.

HON. MEMBER OF THE SOCIETY.

I BEG to offer to the Society an account of the boundaries and position of the serpentine formation, occurring in the vicinity of the Lizard Promontory. I have followed the complete outline of the coast from the Loe Pool to the Helford River, and by crossing the interior of the country in various directions, have, I believe, made out the junctions with as much accuracy as the state of enclosure will permit. There being no map with the elevations distinguished, I have been obliged to content myself with marking out the boundaries on Martyn's Map of Cornwall. The Society is indebted to Capt. Halliday for the drawings of the cliffs and strata.

The slate, which is the general boundary of the district, rests on the granite ridge beyond Helston on the North, at Constantine on the

east, and at Breage on the west: it contains beds of greywacké. Fine sections of these strata, singularly contorted, may be observed near Gunwalloe cove. Slate prevails as far as a small cove a little north of Mullyan, called Bollerium, dipping south-east at an angle of about 40°, and, judging from its inclination, appears to underlie the greenstone, which then succeeds. The latter rock occasionally crops out through the serpentine of Goonhilly downs. It is sometimes slaty, distinctly stratified, and may be seen to lie under the serpentine, on the south side of Mullyan cove, near to which it again forms the barrier to the sea as far as Vellan point: a small quantity of diallage is occasionally intermixed with this greenstone; the predominating ingredient however is common hornblende. Steatite has been raised lately from a distinctly marked vein near Mullyan church-town. The mines of copper have been discontinued. I was informed that at low water, in spring-tides, narrow veins of native copper may be observed in the serpentine where it is covered by the sea. A mass of native copper ore was raised from the mines of the weight of 104 pounds.

Among the beautiful group of rocks forming Kynan's cove, reddish-brown diallage occurs, and dykes of felspar porphyry. The slate of the Lizard promontory commences at Gehilion, and dips south at an angle of about 60°: the serpentine rests on a bed of reddish talc, which

dips north: the intermediate space is filled by greenstone. Veins of fibrous carbonate of lime and of agate occur in the serpentine near the junction. Mica slate then appears, and continues to the west side under the light-house. Under the slate, at the Old Lizard head, are alternating beds of compact felspar and green talc, of considerable thickness. Greenstone continues along the coast from thence to a mile beyond Cadgwith; the inclination of the strata is north, at an angle of about 30°. Near the last village is an extraordinary natural amphitheatre, the area of which is nearly two acres, and the sides about 200 feet in height: the sea enters through an arch near the bottom, where the position of the serpentine on the greenstone is very obvious. The most compact serpentine of this district is found at the Balk Head in Llandewednack; it is, however, but ill adapted for purposes of ornament, taking a bad polish, as appears from the slab in the museum of the Society, which was cut from a large block raised at this place by my directions: the prevailing colour is green, with red spots near the surface, owing probably to the oxydation of iron, as they do not appear at a greater depth.

Serpentine, containing small masses of emerald-green diallage, or schiller-spar, constitutes the coast from hence round the Black Head to Coverack Cove; a place highly interesting to the mineralogist, as offering a series of rocks intermediate between serpentine

and diallage rock: these consist of green and reddish-brown serpentine, with the jade of Saussure, (the feldspath ténace of Haüy) and diallage of the green and metalloïde varieties: the latter substance shews here very distinctly those characters which distinguish it from hornblende, viz. its inferior hardness, its difficult fusibility into a green enamel, and its peculiar cleavage, which discovers a considerable lustre in one direction that is entirely wanting in the other; whereas hornblende has natural joints of the same lustre in two directions. Some of the felspar found here is of a violet colour, and is striated like that of Labrador. I broke masses of diallage metalloïde, six inches in length, from beds lying below high-water mark in Coverack Cove. I had an opportunity of shewing some of these to the Abbe Haüy at Paris, and of comparing them with his specimens brought from the hill of Mussinet near Turin. M. Haüy observed, that the specimens from Coverack do not consist of pure diallage, but that fibres of common hornblende interrupt its texture; that of Mussinet is foliated, and has no such intermixture. The composition of serpentine may be very well seen at Coverack. I conceive that, besides diallage and compact felspar, a portion of talc or steatite is essential, the intimate mixture of the two former substances alone, forming a compound more resembling greenstone.

A very beautiful rock commences at Coverack, and continues for three miles along the coast, and in the interior through the greater part of the parish of St. Keverne. It consists of felspar and hornblende, with an occasional intermixture of diallage, and contains imbedded masses and crystals of felspar: from its great beauty and hardness, it seems eminently adapted for purposes of architectural ornament: columns and blocks of any required size may be obtained near the coast, from whence they might be easily shipped. Greenstone, similar in appearance, and in the direction of the strata, to that of Cadgwith, occurs at Porthoustock; and serpentine on the south-west side of Porthallo, resting on reddish talc, which lies, as before, on clay slate. No further variety is observable from hence to the Helford river, except a conglomerate near the Dennis creek, in which Capt. Halliday noticed veins of quartz traversing the large rounded pebbles of which the rock consists. In the interior of the country, the surface of Goonhilly downs consists principally of serpentine, as may be traced by the growth of the erica vagans, which seems to find something congenial in a magnesian soil. In a quarry of limestone on the downs, I no-noticed chalcedony, and a granitic porphyry near Mawgan, the position of which I could not ascertain.

The result of these observations seems to be, that if the slate which is deposited on the

side of the central granite ridge, is to be considered as primitive slate, of which it bears the external characters, the serpentine and diallage rock (gabbro) occur here in the same geological position which they have been found to occupy in the various parts of Europe where they have been noticed.

In the diallage rock, at a small village near the coast, called Gwendra, and also in the rock of St. Keverne, I observed some small metallic specks, which on chemical examination I found to consist of iron, with a portion of titanium, as was shewn by the precipitate thrown down by tincture of galls: it appears most probable that these particles, carried down by streams to Menacchan, near to which place the St. Keverne rock has been traced, constitute the peculiar sand in which the metal titanium was first discovered by Mr. Gregor. I sent some of this substance immediately on having noticed it to Mr. Gregor, who informed me, by letter, that the result of his experiments proved it to be an assemblage of several ingredients, viz. silica, alumina, and the oxides of titanium and iron, with a little potash: some of these ingredients might be derived from the gangue with which the metallic substance is intimately mixed. I lament, that the subsequent illness of Mr. Gregor prevented him from completing the experiments he had commenced.

V.—*Hints on the Geology of Cornwall.*

By Sir HUMPHRY DAVY, LL.D. F.R.S. &c. &c.

HONORARY MEMBER OF THE SOCIETY.

Communicated in a Letter to Henry Boase, Esq. Treasurer.

I SHALL in this letter comply with the request that you did me the honour to make, of offering a few hints respecting the geology of Cornwall. I can hardly venture to hope that they will be worth the attention of the Society: most of the members have had much better opportunities than have occurred to me, of examining our interesting county; and I dare say that many of the observations which I shall make, will have been anticipated by others: at all events, this communication will shew the desire I have to co-operate in promoting the useful objects of the Society, and I trust they will consider it as a proof of my respect.

Cornwall may be regarded καλλεξοχην as the *Country of Veins*. It is in veins that the

most useful as well as the most valuable minerals generally exist; that the pure specimens are found which serve to determine the mineralogical species, and that the appearances seem most interesting in their connexion with geological theory. Thus veins, which now may be considered in the light of the most valuable cabinets of nature, were once her most active laboratories; and they are equally important to the practical miner, and to the mineralogical philosopher.

Amongst the veins of Cornwall, most curious in a geological point of view, are those of *granite*. These formations are extremely numerous. As far as I am acquainted with them, they intersect either micaceous schist, or other granite rocks. The most remarkable instances known to me in Cornwall, are those on the south-east extremity of St. Michael's Mount, those near Mousehole Cove, those at Zennor, and on the east and west sides of Cape Cornwall.* At St. Michael's Mount the granite veins contain fragments of micaceous schist, and whoever examines without prejudice the different formations, cannot, I think, doubt that the vein has been produced in a chasm of

* I first observed the granite veins of Cornwall about eighteen years ago; probably before, and certainly to a great extent since, they have occupied the attention of geologists, and they are too well known to the Geological Society to require any topographical history from me.

the rock in which it occurs, and that it is consequently *posterior* in formation.

Similar instances of veins of granite are described by mineralogists; a very interesting one was shewn to me at Killiney near Dublin, by Dr. Blake: some in the Isle of Arran, and in other parts of Scotland, are well known. I have seen several cases of granite veins near Morlaix in Brittany. I do not know that any analogous formations have been observed in the great mountain chains of Europe. I have looked for them in vain in the points of junction of the schist with granite, both in the Maritime, Savoy, Swiss, and Tyrolese Alps, and likewise in the Oriental Pyrenees. My researches have not been extensive or minute, but I should be disposed to conclude from what I have seen, that granite veins are peculiar to the low metalliferous granite and mica schist formations.

There are deposited in the museum of the Royal Institution, three specimens of fragments of micaceous schist included in granite, which are from Cornwall; two from St. Michael's Mount, and one from St. Just. At the points of junction of micaceous schist with the low granite, in various cases which I have seen, rocks of granite occur, containing considerable portions of the schist; this is particularly the case at Killiney in Ireland, and near Balyhulish in Scotland. I have seen similar instances in the granite used for building in Mayence, in

France; and in a pillar of granite, which was erected some years ago to Buonaparte at Marseilles, there is a very large fragment of mica schist.

The place where the granite joins the schist in St. Michael's Mount, is remarkable for the number of crystallized substances it contains; oxide of tin, wolfram, phosphate and fluate of lime, quartz, mica, felspar, topaz, are all well known to occur in the same veins; and the particular investigation and history of the nature of the crystallized bodies occurring in this beautiful and remarkable spot, appears well worthy of the attention of the Geological Society, established so immediately in its neighbourhood.

An opinion has been expressed by a foreign naturalist, who was extensively employed in geological researches some time ago by the Geological Society of London, that the granite veins of Cornwall are mere protuberances of primary granite in which mica schist has formed. This opinion does not merit discussion, and could only have been formed in consequence of very superficial examination. It might, with nearly as much reason, be stated, that the veins of copper and tin belong to a great interior metallic mass, and that they existed prior to the rocks in which they are found. The notion that these veins are contemporaneous with the rock is more plausible, and a forced explanation of many of the phe-

nomena might be given on this view; but it is contradicted by the fragments of mica schist found in the veins.

The porphyry of Cornwall in general seems to belong to the dyke or vein formation, and its history is an object of considerable geological interest. The northern shores of Mount's Bay exhibit great varieties of this substance, and it contains a number of crystallized substances which intersect it in veins. A most remarkable vein of this kind was worked some years ago at the Wherry mine near Penzance; the principal metals were oxide of tin, and sulphuret of copper; but ores of cobalt and lead likewise occurred, and the variety of metallic substances found with them in minute quantities was very extraordinary. I have seen in the refuse heaps blende, oxide of uranium, oxide of titanium and of iron, pechblende, nickel, and arsenical pyrites; and in a single piece of the vein, of a few inches square, many of these substances might be found imbedded in quartz or chlorite.

A very good account of the working of this mine has been drawn up by Mr. Hawkins, one of the members of our Society, and published in german; and I have seen a french translation of it in the Journal des Mines. This paper, in an english dress, ought to be placed in the archives of the Geological Society of Cornwall, and is worthy of being inserted in their first publication, as a record of the in-

dustry and ingenuity with which great natural obstacles were overcome. The Wherry mine is the only instance, I believe, that has ever occurred of a shaft sunk in the ocean; and of a mine worked, the only access to which is below low water mark.—(See pl. 1).

The *serpentine* district of Cornwall has not yet met with the attention it deserves. I have seen no formation in which the nature of serpentine is so distinctly displayed. The true constituent parts of this rock appear to be resplendent hornblende and felspar; it seems to differ from sienite only in the nature of the hornblende, and in the chemical composition of its parts, and in being intersected by numerous veins of steatite and calcareous spar. Near Coverack cove, the felspar and resplendent hornblende forming the rock, occur in crystals of some inches in size; and from this size there is a gradation to crystals so minute, that the rock appears of a simple nature. The green or red colour of the hornblende is generally the cause of the peculiar tints of the rock; the felspar is generally white; but in instances at Coverack, some of the large crystals of felspar are of a reddish hue.

The nature and origin of the veins of steatite in serpentine, are curious subjects of enquiry. Were they originally crystallized and the result of chemical deposition? or have they been (as for the most part they are now found), mere mechanical deposites? I am inclined to

the last opinion. The felspar in serpentine is very liable to decompose, probably from the action of carbonic acid and water on its alkaline, calcareous, and magnesian elements; and its parts, washed down by water and deposited in the chasms of the rock, would necessarily gain that kind of loose aggregation belonging to steatite.

I made, some years ago, a rude comparative analysis of the felspar in serpentine, and of the soap rock. I found the same constituents in both of them, except that there was no alkali nor calcareous earth in the steatite, but my experiments were not so exact as to determine the proportions. It is not easy to conceive that steatite was originally a crystallized substance which has been since decomposed; for in that case it ought to be found in its primitive state in veins excluded from the action of water and air; and it is not difficult to account for the hardness of some species of steatite on the hypothesis which I have stated. Mere mechanical deposites, when very finely divided, and very slowly made, adhere with a considerable degree of force. A remarkable instance of this kind has occurred to me; amongst the chemical preparations of the late Henry Cavendish, Esq. which were given me by Lord George Cavendish, there was a bottle which had originally contained a solution of silica by potassa; the cork had become decayed during the lapse of years, and the carbo-

nic acid of the atmosphere had gradually precipitated the earth, so that it was found in a state of solid cohesion; the upper part was as soft as the steatite of the soap rock, but the lower part was very hard, was broken with some difficulty, and had an appearance similar to that of chalcedony.

The felspar of serpentine seems to differ from that of other rocks, in containing a much larger proportion of magnesian earth; but many varieties of felspar are liable to decomposition; the porcelain clay of St. Stephens is well known to be the result of a process of this kind.

I have seen a specimen of porcelain clay from a mine in the west of St. Just, which contained a quantity of magnesia, and which appeared to be produced by the disintegration of felspar. It occurred in a quartzose vein, which afforded oxide of tin. Copper, I believe, is the only metallic substance that has been found in any quantity in the serpentine formation of Cornwall, and crystallized substances in general are rare in the cavities of this rock. In America, chromate of iron is found in serpentine; and in the serpentine of the coast of Genoa, Professor Viviani has shewn me arragonite, and a peculiar crystallized stone analogous to crysolite. The relation of the Cornish serpentine to the neighbouring rocks is worthy of examination; towards the north it seems to pass into micaceous schist; at the point of Cape Lizard it is bounded by stratified sienite, and

white micaceous schist. In Kynan's Cove, so remarkable for the beauty of the forms of its cliffs, and for the number of their caverns, there is a protuberance of granite above the white sand. I do not believe that the Cornish serpentine has, as yet, been applied to any purposes of architecture or sculpture, and in general at the surface its parts are too small, and contain too many fissures to be worked with advantage; but I am convinced, that by making proper excavations, many parts of the serpentine district would afford large and beautiful blocks of great fineness and beauty of colour.

The serpentine of the Appenines is in general very like that of Cornwall. During an examination of the coast of Italy, that I made between Genoa and Massa, I found, a few miles from Sestri di Levanto, an ancient quarry bearing marks of having been worked by the Romans; but which, amongst the profusion of marble furnished by the neighbourhood of Carrara, and amidst the quantities of ancient remains of verd antique, is neglected by the modern Italians.

I hope some members of the Society will examine the black marble of the north coast of Cornwall. From a superficial examination that I made of a part of this district, it appeared to me to be of the same formation as the Plymouth marble.

I am ignorant whether any true basalt exists in Cornwall. Near Port Isaac I have seen on

the road wacké or mandelstein, but I do not know where it was quarried. A sienite, resembling the Scotch grunstein, is very common on the eastern border of the county: but I am inclined to believe that it belongs to the primary formation.

Though the whole of Cornwall is of a very peculiar mineralogical construction compared with the rest of Britain, and even of Ireland, yet it bears very a considerable relation to the opposite coast of France. The mica and chlorite schist, and the granite (the killas and growan) in the neighbourhood of Morlaix in Brittany, I find precisely similar to those of Mount's Bay, and containing similar kinds of actinolyte and thumerstein; and I saw at Morlaix specimens of serpentine (said to have been brought from the neighbourhood of Rosloff) similar to those of Cape Lizard.

Veins of tin have been worked in the low French granite formation; but as yet they have not been productive.

The conformation of Cornwall is in the highest degree curious, and the facts it offers are illustrative of many important points of geological theory. It exhibits very extraordinary instances of rocks broken in almost every direction, but principally from east to west, and filled with veins again broken in, diversified by cross lines, and filled with other veins, and exhibiting marks of various successive phenomena of this kind.

Respecting the agents that produced the chasms in the primary strata, and the power by which they were filled with stony and metallic matter, it would be easy to speculate, but very difficult to reason by legitimate philosophical induction.

The water-worn pebbles of chlorite schist found cemented by oxide of tin, and of which an interesting account has been given by a member of the Society, render it probable that the operation of water, either in the beds of rivers, or on the shores of lakes, or the ocean, preceded or accompanied the operations by which veins were produced and filled. All *crystallization* must be preceded by *chemical solution*, or by a division of matter tantamount to *solution:* and elevation of temperature offers the most obvious means of explaining the production of combinations capable of depositing crystals.

Amongst the ancient lavas of Radicofani, I have seen crystals having the characters of felspar imbedded in a black semi-crystalline mass, so as to constitute porphyry; and I am in possession of a specimen from Vesuvius which I ascertained to belong to a stratum of lava containing a cavity, in which felspar and mica have crystallized in their regular forms, and the separation and geometrical arrangement of their elements have evidently been the result of slow cooling.

The lavas of Languedoc, of the Vivarais, of Andernach, and of the Siennese, and Roman states, offer numerous instances of the formation of tufas, which consist of *separate* crystals, and which have assumed the columnar arrangement. Near Aix in Provence, I have seen a dyke between strata of limestone, which, at its lower extremity, has the character of *basalt*, and it is arranged like a basaltic dyke in regular horizontal prisms; but its upper edge has the characters of amorphous lava; and where it has been decomposed and worn to a great depth by the operation of a torrent, it has all the characters of a primitive sienite, being composed of large crystals of hornblende and felspar.

It is amongst extinct volcanoes, the surfaces of which have been removed by the action of air and water, and in which the interior parts of strata of lavas are exposed, that the most instructive examples of the operation of slow cooling upon heated masses are to be found. It is difficult to conceive that water could have been the solvent of the different granitic and porphyritic formations; for in this case, some combinations of water with the pure earths ought to be found in them. Quartz ought to exist in the state of hydrate; and wavellite, not corundum, ought to be the state of alumina in granite.

To suppose the primary rocks in general to have been produced by the slow cooling of a

mass formed by the combustion of the metallic bases of the earths, appears to me the most reasonable hypothesis; yet aqueous fusion must not be entirely excluded from our geological views. In many cases of crystallization, even in volcanic countries, this cause operates. Thus in Ischia, as well as in Iceland, siliceous tufas are formed from hot springs; and in the Lake Albula, or the Lake of Solfaterra, near Tivoli, crystals of calcareous spar and of sulphur, separate from water impregnated with carbonic acid and hepatic gas; and large strata of calcareous rocks, formed evidently in late times by water impregnated with carbonic acid, exist in various parts of Europe. The Travertine marble, (marmor Tiburtinum) is a production of this kind, and it is of this species of stone that the coliseum at Rome, and the cathedral of St. Peter, are built. It is likewise employed in the ancient temples of Pæstum, and it rivals in durability, if not in beauty, the primary marble of Paris and Carrara.

VI.—*Observations on a remarkable change which Metallic Tin undergoes, under peculiar circumstances, and on its partial conversion into a Muriate of Tin.*

By the Rev. WILLIAM GREGOR,

MEMBER OF THE SOCIETY.

I BEG leave to submit to the Society some observations on a remarkable change which metallic tin undergoes that has long lain under the surface of the earth, and on its partial conversion into a *muriate*.

I shall not trespass upon the time of the Society by entering into the minutiæ of chemical analysis, much less shall I indulge myself in the reveries of speculation and conjecture. I shall merely state some facts which may excite their attention, and direct their enquiries to this particular subject; so that when the peculiar circumstances under which the phenomena in question take place, are clearly ascertained, we may be furnished with data on which we may found our reasonings, and approxi-

mate more nearly to probability when we attempt to connect effects with their corresponding causes.

The first instance in which I saw *muriate of tin*, occurred in a specimen of what is usually called "*Jew's House Tin*;"* it was kindly presented to me many years ago, by Mr. John Michell, of St. Austle. It was amongst other lumps discovered under the surface of a low and boggy ground in the parish of Kea; the tin was accompanied with a stratum of charred wood or charcoal. The first thing that struck me in this mass of tin, was a vein of saline matter that ran through it; this saline matter I found to my astonishment to be *muriate of tin*. The whole mass evidently appeared to be in a state of decomposition. There was also a marked gradation in the several changes which the metal had undergone; one part of the mass had the appearance of metal, which, although some change had taken place in it, could, to a certain degree, be extended under the hammer. This metal in the next layer, began to be split into fragments, which still adhered together;

* It may be necessary to state the meaning of the term "*Jew's House*." It is a plot of ground that has been hollowed out, and is found to contain ashes and often fragments of metallic tin, which has given rise to the fallacy respecting the discovery of that metal in a native state; these ancient remains of the places where tin was formerly smelted by the Jews, are frequently found in different parts of the county.

they occasionally exhibited spots of the colours blue and yellow. The next layer was still further changed, as it had assumed the appearance of a brown earth or oxide, through which a white brilliant salt shot, here and there, in mammillary protuberances. Next to this brown oxide a regular vein of crystallized salt occurred; it was of a yellowish hue, and was compact and hard; the vein was nearly one fourth of an inch in thickness. The outer surface, to which it was strongly attached, was also about one-fourth of an inch in thickness; was black, and so hard that angular fragments of it were capable of scratching glass. I do not mean to affirm that these several states or stages of progressive decomposition or change in this mineral substance, were so *distinctly discriminated* as not here and there to run into each other, for this indeed was true with respect to all, except the hard black matter, which lay next to the vein of muriate of tin; the line of separation was *here* distinctly marked.

The *metallic* tin has, evidently, undergone some change since the mass has been in my possession, and some saline matter has shot forth from the brown oxide, and still continues to shoot.

The form of the crystals of this *muriate of tin* appears to be that of square laminæ, the opposite angles of which are frequently truncated. These laminæ are closely packed together in a mass in the vein of the salt before mentioned.

In some pieces, where there has been a fissure in the mass, these laminæ are distinct, and the salt is very beautiful as it assumes a silvery brilliancy. These crystals, and the black hard substance to which they adhere, might be easily mistaken, even by an experienced mineralogist, for a natural production, in the strict and usual sense in which the word "*natural*" is employed in such cases; nor is it probable that he would be competent to decide upon the nature of the fossil, much less upon the origin from which it had been derived. This muriate of tin is almost totally soluble in distilled water; a small portion of oxide remains undissolved; whether this residuum arise from the salt being not quite pure, or from a change in the oxidation of the tin, produced by the process of solution, I do not know; liquid nitrate of silver, dropped into a solution, recently made, produces a copious precipitate of a chesnut colour. After some time a portion of the oxide of tin is separated, and *then* the precipitate effected by the nitrate of silver, is not tinged brown, but is white. I could by no means satisfy myself with respect to the chemical analysis of this *muriate of tin*. In addition to the difficulty (I may say impossibility) of accurately ascertaining the amount of the muriate acid by means of the *nitrate of silver*, for the reasons given by one of our members, Dr. John Davy, in his masterly observations on the combinations of different

metals with chlorine; another source of error arose from the intrusion of small particles of tin, and of the brown oxides, a circumstance which would preclude accuracy, in any estimate formed by means of *inference and calculation*, from the quantity of tin found in the salt. I melted twenty-five grains of this salt, freed as far as it was possible from extraneous matter, with double its weight of the purest carbonate of potash that had been dried in a red heat, in a platinum crucible; extracted the soluble part by means of distilled water, and rendered the solution slightly acid by dropping into it pure nitric acid. Liquid nitrate of silver dropped into it separated muriate of silver, which, after having been perfectly dried, weighed 12.6 grains; but I have reason to think that all the muriatic acid was not separated by the alkali, and therefore that the relative amount of muriatic acid in this salt is not duly represented by the muriate of silver. The oxide of tin which remained after all the soluble part had been washed out, resisted the action of muriatic acid with singular obstinacy. The brown oxide before mentioned, contains muriatic acid, as we might suppose from the circumstance of crystals of *muriate* of tin shooting out from it. Some nitric acid of moderate strength was poured on some of it reduced to powder; I was surprised to see that the acid dissolved the greater portion of it, and retained it in solution also, even after it

had been considerably diluted with water. A drop of liquid nitrate of silver threw down a precipitate of a deep chocolate brown colour. I separated an abundant quantity of oxide of tin from another portion of this solution by means of ammonia; the residuary fluid, after being neutralized by nitric acid, was assayed with liquid nitrate of silver, which separated muriate of silver, no longer tinged brown, but which was white.

I have seen some other masses of "*Jew's House Tin*" in an early stage of decay, wherein the metallic tin was breaking into fragments, and gradually passing into an oxide; but I doubt not, but that under favourable circumstances of time, &c. they would have advanced through all the stages of change before specified. Nitric acid poured upon some of this partially decayed metal, converted it into a white oxide; the soluble part was then extracted by distilled water; liquid nitrate of silver dropped into it separated a precipitate of a chesnut colour; it consisted of oxides of silver and tin, a *trace* also of the presence of muriatic acid was discovered, which was still more evident when some of the same substance was fused with pure potash, &c. &c. This agrees with the result of trials made upon portions of the mass first mentioned, which was in the first stage of decay. I have seen other lumps still farther decayed, in which I could here and

there detect a few crystalline laminæ. I was much struck by a passage which I met with in Mr. Phillips's ingenious and scientific memoir on the *oxyd of tin* in the second volume of the Transactions of the Geological Society of London—" This specimen (of supposed native tin) seems very much to agree with some found in France by Schreiber, an account of which he has given in the Journal des Mines, except that those were accompanied by a white substance, which proved to be white muriate of tin."

It appears then from what I have had the honour of submitting to the Society, that the gradual conversion of tin into a muriate, is not an isolated fact: but there seems to be in this metal a tendency to change, a liability to very gradual and progressive alteration, *under peculiar circumstances.* What *all* these circumstances are we are not warranted by adequate data to affirm. I will, however, hazard one observation; it is this, that the pieces of tin which I have seen undergoing the change, have all agreed in this one particular, that they were found under the surface of boggy ground, where we may suppose that sulphuretted hydrogen gas is generated. It has indeed been suggested to me that the muriatic acid may owe its origin to muriate of soda, which might have been used as a flux for fusing the metal. The probability of this supposition seems to be negatived *a priori* when we consider how rude

and summary the process of fusion was in ancient times; the stratum of charred wood which generally accompanies these lumps of tin, proves that the ore was not confined within the limits of a furnace, but exposed to an open fire. If muriate of soda had been employed and decomposed, some traces of the presence of soda would be discoverable. On my employing the usual modes, I could detect no trace of it, or of potash.

I flatter myself that the Geological Society of Cornwall will consider the facts which I have submitted to them, not altogether uninteresting, and that they will deem them worthy of being followed up by further and more scrupulous investigation. An accurate examination of the spots where *such* lumps of tin have been found, and a more minute and rigid analysis of them in the several stages of change, both by the ordinary methods as well as by the means of pneumatic chemistry, might afford some interesting results, and possibly lead to some curious conclusions, which might tend to establish truths of *general application.*

It cannot be expected that we can produce in our laboratories any change in tin similar to those changes which I have described; for chemists cannot call to their aid an auxiliary essential to such a process; I mean that silent, secret, yet powerful agent, TIME.

I ought to apologize for using some antiquated terms in this paper, such as muriatic

acid, &c. which are now superseded by terms more appropriate, *chlorine, stannane, &c.*; and above all I feel that an apology is due for the jejuneness of this paper; the fact is, that the few experiments which I made on the tin were made some time ago, and for a long season I have been prevented from extending and multiplying them; but I choose to send this memoir *with all its imperfections on its head,* rather than to omit an opportunity of shewing my respect for a Society so eminently calculated to promote the interests of the county, and of which I have the honour of being a member.

Creed, September 7, 1816.

Since writing the above, I have visited Menabilly, where I saw two specimens of "*Jew's House Tin.*" Both were in a state of gradual and apparently increasing decay, and both contained crystals of *muriate* of tin; one of the specimens had a vein of this salt running through it, beautifully crystallized. I could not learn whence these specimens came; they were, however, supposed to have been found in a low swampy ground.

February 12, 1817.

VII.—*Observations on the processes for making the different Preparations of Arsenic, which are practised in Saxony, and on those for preparing Smalt or Cobalt, as pursued in Bohemia.*

Communicated in a letter to JOHN AYRTON PARIS, M. D.

BY JOHN HENRY VIVIAN, ESQ.

YOU have frequently done me the favour to ask me for some information on the subject of the mines and smelting works which I had an opportunity of examining during my travels on the continent. It was fully my intention to have furnished you, before this, with a memoir on the Saxon and Hungarian mines, and I regret that other business has hitherto prevented me; anxious, however, to shew the interest I take in the success of the Society of which you have shone so conspicuously as the founder, I am unwilling to leave the county without complying with your request, although

I fear the communication is little worthy of your consideration.

Having heard, a few days since, that an establishment in Cornwall had to contend with considerable difficulties in making the different preparations of arsenic, it occurred to me that it might be advantageous to give publicity to some remarks I had an opportunity of making during my last visit to Saxony, on the methods practised in that country; having had the good fortune to be admitted to examine in *detail,* all the works carried on for that purpose. To these I shall add some remarks on the method of preparing *smalt* or *cobalt,* which it is well known is imported into England from Saxony, at the very time that cobalt ores have of late been found in considerable quantities in this county.

I should state that, in Saxony, the cobalt works belong to the sovereign, and that strangers are not admitted to see them; having received great civilities from the managers of all the other establishments, I did not attempt it; it is from those of Bohemia that the information is derived which I shall communicate, and the processes, I understood, were the same as those of Saxony.

The preparations of arsenic are of four sorts, distinguished in commerce by their colours; viz.

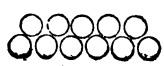
1. *The Grey or Black,* which is arsenic in the *metallic* state.

2. *The Red,* a compound of the metal and *sulphur.*

3. *The White,* an oxyd of arsenic.

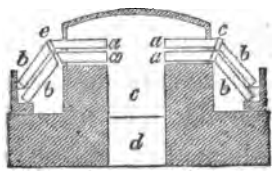
4. *The Yellow,* a compound of the oxyd with *sulphur.*

The two first are made entirely from the *arsenical pyrites,* or *white mundic* of the Cornish miner. The oxyd and its compound may be prepared from the sublimated arsenic from the tin burning-houses; indeed I doubt not but the metal itself might be obtained from the burning-house sublimate, which is chiefly an impure oxyd, by reducing it with charcoal powder or iron; and in case of its containing much sulphur, a little potash might possibly be added with effect, or it might be subjected to a second roasting, during which a great part of the sulphur would burn off. The method by which in Saxony they prepare the *red,* or sulphuret of arsenic, is by mixing equal quantities of the common pyrites, or *mundic,* and of the arsenical, or *white mundic,* in a cylindrical earthen retort about two feet in length, and six inches in diameter at the mouth, tapering a little towards the end. Twenty-two of these retorts, containing about four cwt. of pyrites, are placed in a reverboratory furnace, eleven on each side, in two tiers, thus,



the lower tier of six resting on the sides of the furnace or fire place, and the upper tier of five lying on them.

The retorts are so placed that the closed ends do not project into the fire beyond the sides of the furnace; the whole are under an arch. The following sketch will represent a section of the furnace and retorts:

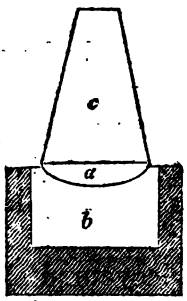


To the mouths of these retorts, which lie horizontally (*a*), and project through holes in the sides of the upper part of the furnace (*c*), below which is the fire place (*d*), others precisely similar are luted with clay (*bb*); and as they form an angle with those in the furnace, a small ring of baked clay is placed on the inside of each at the point of junction to assist the luting (*ee*). It may be observed that the *pyrites* in the retort should not be too fine, or it will be liable to bake together. The furnace being thus prepared, a tolerably strong fire is given for eight or ten hours, and a *sublimate* comes over and forms a *glass* in the receiver, which is taken out, when sufficiently cool, and

afterwards purified. This is done by melting it in a cylinder formed of sheet iron six or eight inches in diameter, burning wood being kept around it. The slags which collect on the surface are skimmed off, and when the mass is sufficiently cleansed, which is ascertained by taking occasionally an assay with an iron rod, it is cast into a semicircular iron pan; it is then of a fine red colour, has a glassy fracture, and a smooth shining surface.

The grey, or metal of arsenic, is prepared in a similar manner, except that *arsenical pyrites* alone are employed, and instead of a ring of baked clay, a piece of sheet iron is placed round the inside of the receiver, where it is connected with the retort to which the sublimated metal attaches itself. When thus prepared, it has a dark grey sparkling appearance. Some impure metal of a dead earthy aspect is likewise obtained in the burning-houses over the mouth of the furnace, being a portion of the sublimated oxide reduced.

The yellow arsenic is a compound of the oxide of arsenic, with a small quantity of sulphur. It is prepared by mixing in a shallow circular cast-iron pan, two cwt. of the impure oxide of arsenic from the burning-house, and a quarter of cwt. of sulphur.



The pans (*a*) used for this purpose are shallow, about two feet in diameter, and are laid in masonry over the fire place (*b*); when the mixture is formed, it is covered with a cap (*c*) of sheet iron, of a pyramidal form, and about four feet in height, and carefully luted at the point of connection. The fire is then kept up for twelve or sixteen hours, and the sublimate, of a fine yellow colour, is found adhering to the sides of the iron cap, from which, when cool, it is easily separated.

The White, or oxide of arsenic, is prepared precisely in the same manner, but without the addition of the sulphur. The sublimate obtained, not being quite pure, undergoes a second and similar operation; it is then quite clear and transparent.

These products are pounded, sifted, and packed in cases for exportation; I was informed that considerable quantities were sent to Eng-

land. The *red* and the *grey* bear the highest price.

The *white* is particularly dangerous to handle, being of the most poisonous nature. I observed running water throughout the works, and the frequent use made of it by the workmen was evident from the lady-like whiteness of their hands.

Having thus endeavoured shortly to explain the method of preparing the different kinds of arsenic, I shall proceed to give such observations as I had the means of making on

The Preparation of Smalt, or Cobalt.

The ores used in the cobalt works of Bohemia, on the frontiers of Saxony, near Johann-Georgenstadt, to which I gained admittance, are chiefly from the mines at Joachimsthal, and are inferior in quality to those used in the Saxon works from the Schneeberg mines.

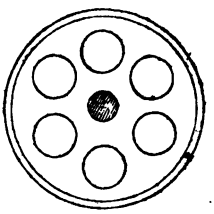
The cobalt ores at Schneeberg occur frequently so blended with ores of silver, that as one or the other metal must be sacrificed, it is often a matter of calculation to which works it will be most advantageous to deliver them. The first point to be ascertained is, the precise quality of the ore to be acted on; this may be done by roasting, or calcining a small quantity, and then melting it with sand or potash, so as to form a glass: it should be observed, that for trials in the crucible, a larger proportion of

potash is required than is used in the mixture for the pots.

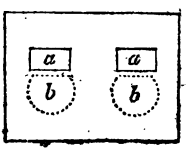
Much depends on giving the ore a proper degree of calcination. If it be overcalcined, the glass from it has a red appearance, and on the other hand, if it be not sufficiently calcined, the glass has a greenish or blackish cast. Calcining too high is to be particularly avoided. Some ores require only one hour's calcination, others two, and some even eight or nine hours; this operation is performed in a common reverberatory furnace, in quantities of three or four cwt. As all cobalt ores contain *arsenic*, some sublimate is obtained from the flues of the calciner, which is occasionally used in small portions as a flux in preparing the glass when the potash is not good.

The ore when roasted is dry-stamped, and sifted; it is then mixed, in the proportion of one to three, with a fine white sand prepared from stamped quartz, and to this mixture about one-third of potash is added; the quantity of potash employed must depend, however, in a great measure, on the purity of the article and on the fusibility of the ores. These ingredients, well mixed, are then put into a circular pot, made of fine clay, about eighteen inches in diameter, and somewhat less in depth. The furnaces in which the fusion is performed, vary in their construction; in one work I observed the furnace was circular, and

contained six pots, in the midst of which is a circular aperture to admit the flame.



In another it was square, and contained only four pots, but the circular furnace appeared to me most advantageous; the fire in each case was below the bottom of the furnace in which the pots stood, and had a circular hole in the centre through which the flame ascended, a strong arch covering the whole. Each pot contains about half a hundred weight of this mixture; when it has been properly fused, which may be after eight or nine hours strong firing, the vitrified mass is laded out through a door in the side of the furnace (*aa*) just above the mouth of each pot (*bb*), and cast into a cistern of water.



Although the usual proportion of sand to the roasted cobalt ore is as three to one, this must

depend materially on the quality of the ore, and on the density of colour required for the glass. For the light coloured glasses, the inferior ores, however, are generally employed.

I should observe, that in the bottom of each pot is a small hole, for letting off the metals which occasionally collect there, and which were contained in the cobalt ore. When not in use, this tap-hole is stopped with clay.

The glass thus obtained is dry-stamped to about the size of common sand, and sifted. It is then ground with water in a stone mill. Two long square stones of a fine grained granite, with grooves in the lower side,

and fastened together by iron bars, are moved round in a large fixed circular trough.

After the mass is well worked about for six hours, it is let off and diluted with water in a tub, where it is allowed to stand for five or six hours more, until the coarser part is deposited; the liquid containing the fine

is then taken out in buckets, put into another and a larger tub, further diluted, and allowed to remain for twenty-four hours. As the fine becomes deposited, the water above is let off by degrees, by means of plugs in the side of the tub, and is passed through a range of pits, in which it deposits any it may still contain. The fine deposit obtained in the tubs is again stamped and washed in the same manner; it is then dried on a hearth, sifted, and prepared for sale.

The assortments of smalt or cobalt are distinguished in Saxony by letters; thus of the *fine*, there are the FFFE, FFE, FE, ME, MES, and OES.

Of the *coarse*, FFFC, FFC, FC.

The coarse sorts feel a little rough between the fingers; the fine are quite a powder. The three F's are the deepest, and finest coloured. The sorts MES and OES are quite pale, scarcely tinged; they are obtained from the pits through which the waste water passes. The coarse sorts appear of a deeper colour than the *fine*, although obtained from the same glass.

I shall be most happy if the information I have thus attempted to give should prove of any advantage to the manufacturers of our county, and I hope I shall shortly be enabled to send you a memoir on some other subject.

VIII.—*A sketch of the plan of the Mining Academies of Freyberg and Schemnitz.*

By JOHN HENRY VIVIAN, Esq.

MEMBER OF THE SOCIETY.

THE establishment of a mining academy in the county of Cornwall has ever been a favourite scheme of mine. I need not therefore dwell upon the satisfaction that I feel at the exertions which the Society is making to establish a chair for a Professor of Mineralogy and Geology; and I beg to communicate that, should the resolutions upon this subject be carried into effect, it is my intention to present to the museum the mineralogical collection which I formed at Freyberg, immediately under the eye of Werner. The following sketch of the plan of the academies on the continent, which I have had an opportunity of visiting, will probably, upon this occasion, be received by the Society with some degree of interest.

The academy at Freyberg, in the Ertzgebirge *(metalliferous mountains)* of Saxony, has been established about half a century. It is supported by the government of the country; the sovereign, as in the other continental states, deriving a considerable revenue in dues, &c. from the mines. Of the three professors belonging to it, two are well known in the scientific world; Mr. WERNER, who lectures on *mineralogy, geology,* and the art of *mining.* LAMPADIUS, professor of *chemistry, metallurgy, assaying,* and *analytical chemistry.* Mr. RUSSE lectures on *mathematics, physics, dialling,* &c.

There are likewise several drawing and writing masters. The students are recommended by the sovereign, and have free admission to the lectures: during the latter part of their residence at the academy, they receive a small stipend. The time allowed for their education is three years. The Board of Directors of the Mines, before whom there is a public examination at the end of every course, which lasts from the summer of each year to the Easter following, regulates the studies of the collegers according to the situations for which they are destined; those intended for the mining department are to attend the lectures on mineralogy, geology, the art of mining, dialling, mechanics, &c.; whilst those for the smelting department, apply themselves particularly to chemistry and metallurgy.

The mines being in the immediate vicinity

of the town of Freyberg, the students are expected to make frequent excursions underground, and to draw up a report of their observations. That they may become thoroughly acquainted with the practical part of mining, a *pitch* is usually allotted to each in a mine near the town, and the student is paid a somewhat higher price than is commonly given, for the work done. At the expiration of the three years, the student is recommended to a situation, if he has regularly passed his examinations, and conducted himself with propriety.

The lectures for the collegers are likewise open to strangers, on their making a moderate compensation for each course to the professor. Mr. Werner in particular had pupils from all the nations in Europe. At the time I studied there in 1804, there were Frenchmen, Spaniards, Poles, Prussians, Bavarians, and one Englishman, Mr. Chenevix. In addition to the public lectures, I had a private course with Mr. Werner, and shall ever feel gratified for the great attentions I received from him as well during my former residence at the academy, as at my late visit in 1815. In fact every one at Freyberg is anxious to forward the pursuits of strangers, and to give them all the information they may wish; the mines and works are always open to inspection, and every thing relating to them is admirably conducted; permission from Dresden is required to study at

the Academy, but it is readily obtained. There is a collection of models, and likewise one of minerals, belonging to the Academy; the latter of which will now be completed by the addition of Mr. Werner's private collection, for the purchase of which the government has lately made an arrangement.

The Mining Academy at Schemnitz, in Lower Hungary, was founded in the year 1760, under the auspices of Maria Theresa; it is supported by the Austrian government, being for the education of young men destined for the direction of mines and smelting works in any part of the Emperor's dominions. As these are very extensive, and as each board of direction of mining districts has the right of recommending several students, their number is much more considerable than at Freyberg. At the time I visited Schemnitz in May, 1815, they were said to amount to nearly two hundred; the period of their studies is likewise three years; but with this difference, that instead of confining themselves, as at Freyberg, to the sciences immediately connected with their future destination, they attend a course of lectures on each, and at the expiration of the three years, if they have passed their examinations, they declare for which line they intend to qualify themselves; if for the mining department, they are expected to reside six months on the mines in the neighbourhood of the town, to learn the practical part of mining,

dressing the ores, dialling, &c.; or if for the smelting department, a residence at one of the smelting works is necessary; they are expected also to go under-ground, at least once a week, during their residence at Schemnitz, in parties of five or six, to assist each other by their remarks.

The student, before he enters the Academy, is supposed to have some general knowledge of mining. The first year he attends the lectures of the professor of physics and mathematics, in which those parts which relate particularly to mining are detailed, as hydraulics, hydrostatics, mechanics, geometry, trigonometry, &c.; this year may be dispensed with if the student from previous application can pass the examination. The second year is devoted to chemistry and metallurgy; the third to geology and mining. Each course lasts five months, with one month vacation. In the lectures on geology, Werner's system is followed, as published by Reichehedz. Mr. Floring, the professor of chemistry, who has studied at Freyberg, has adopted the English system of Dr. Thomson. Mineralogy is treated of in the course on chemistry. I confess it appears to me too important a part in the education of a miner, to be passed over thus slightly.

The mineralogical collection, I must also observe, was very incomplete and carelessly arranged. In justice, however, to the professors, I must add that they had not been long at the

Academy, and that they observed that the collection had, from time to time, been stripped of its finest specimens for the embellishment of the cabinet at Vienna. Mr. Handstedn, the professor of geology and mining, who lately returned from a tour through Transylvania, shewed me some very fine specimens of native gold and of the ores of tellurium.

Amongst those who have been professors at the Schemnitz Academy since its establishment, the following have distinguished themselves by their writings :—Mr. Delius *on mining*; Scopoli *on smelting*; and Potzier *on chemistry*. The present professor Wilkins is said to be an excellent mathematician.

On my passing through the Hartz mountains in the autumn of the year 1815, I found that since I was there in 1804, a person had been appointed to lecture on mineralogy at Clausthel, which it was hoped would lead to an establishment of a mining academy.

In England, until the resolutions of the Royal Geological Society of Cornwall, no attempt has been made to establish a mining academy. It may be said that our government is not so materially interested in the mineral productions of the country as those of the continent, where all metals belong to the state; and the sovereign, in granting permission to search for them, reserves to himself the appointment of the principal officers who have the direction of the mines and works, as like-

wise the purchase of all the ores obtained; but it is not to be denied that the metals contribute largely to the prosperity and welfare of a state, and it may be asserted with equal truth, that in this respect the kingdom of Great Britain in general, and the county of Cornwall in particular, are, by the bounty of nature, singularly favoured.

IX.—*On the Accidents which occur in the Mines of Cornwall, in consequence of the premature explosion of Gunpowder in blasting Rocks, and on the methods to be adopted for preventing it, by the introduction of a Safety Bar, and an instrument termed the Shifting Cartridge.*

By JOHN AYRTON PARIS, M.D. F.L.S.

MEMBER OF THE SOCIETY.

THERE is no maxim more erroneous than that which ascribes to mankind an innate love of novelty; the history of almost every art and invention affords a proof that the very contrary obtains, whilst at the same time it furnishes the no less important fact, that in overcoming the powerful prepossessions of habit, and the obstinacy inseparable from routine, the influence of rank has not unfrequently proved more successful than the force of argument, and that the human mind, thus warped, has yielded to

the impulse of fashion that compliance which it had denied to the claims of truth, and the solicitations of reason. Thus it was that Louis XV, by wearing a bunch of the flowers of the potatoe, in the midst of his court, on a day of festivity, did more towards the eradication of the vulgar prejudices which then existed against the introduction of that valuable root, than all the philosophers of Europe for more than two centuries. I relate this anecdote with a view to vindicate the propriety of an appeal to the nobility, and gentlemen of personal influence in the county, for their countenance and support, or even of an application to his Royal Highness the Prince Regent, who has graciously condescended to become the patron of our Geological Society, for his recommendation of a plan which has no less an object than that of the PRESERVATION OF A LARGE AND VALUABLE PORTION OF THE COMMUNITY FROM SEVERE BODILY INJURIES, AND UNTIMELY DEATH, but which has to contend with all the inveterate prejudices which exist against every innovation upon an established system, however erroneous it may be in principle, or dangerous in application. From what I have thus stated, the duty of the Royal Geological Society of Cornwall becomes apparent; and the efforts which it has made, and still continues to make, in order to facilitate the introduction of the SAFETY INSTRUMENTS, which form the subject of this paper, must be regarded as no less appropriate

than laudable: for it may be truly said to have concentrated within itself all the rank, talent, and science of the county. It is by the desire of the Council that this essay is printed; and in stating to the public the grounds upon which such a resolution became expedient, I cannot conceal the fact, that the efforts of the Society have been treated by many Mine Agents with coolness, and by some even with hostility; that the extent and frequency of the calamity, arising from the accidental explosion of gunpowder have been denied; and that letters addressed to me through the medium of one of the provincial newspapers, have called upon me to produce evidence in support of the truth of such an assertion. I have accepted the challenge, and I now produce such a catalogue of human woe as has been but rarely witnessed; and which, whilst it must chill with horror the blood of every person who peruses it, will, I trust, for ever set at rest the question, and silence the voice which would contend against the necessity of some immediate and effectual remedy. In alluding to the angry letters addressed to me upon the subject, I am sure that I entertain no feeling of personal acrimony towards their authors, nor indeed can I see why the subject should awaken ill humour, and much less excite invective, for it alone respects the public good, and the interests of humanity; but since necessity obliges me to

declare the opposition experienced from some of the mine agents, so candour, on the other hand, demands that I should acknowledge with gratitude the liberal assistance and co-operation which has been received from others; whilst by ALL, a sense of the utility of the SAFETY BAR has been frankly acknowledged, or unintentionally betrayed.

The limits of this paper will not admit of a diffuse disquisition upon the nature and theory of the different processes employed for blasting rocks with gunpowder; the injuries however which arise from them, and the methods by which the operation may be disarmed of its dangers, must form a subject of general as well as local interest, since rocks are rent in every part of the globe, either for the purpose of preparing the surface of the earth for the cultivation of its fruits, or for that of penetrating its interior for the discovery of its treasures. I have therefore thought it expedient to offer a popular account of the operation of blasting, as it is performed in the county of Cornwall, in order that the measures of safety, which we are so anxious to introduce, may be generally understood, and their value more fairly appreciated.

The first part of the operation consists in boring a cylindrical hole, about an inch in diameter, and two or more feet in depth, as circumstances may require; this is effected by means of an iron instrument, resembling a

blunt "*cold chisel*" which is held by one miner, who shifts it gradually round after every blow which it receives from a mallet directed by another, the abrasion of the rock being at the same time facilitated by the occasional affusion of water. When the hole has been thus effected, it is "*swabbed out*" by a staff, the ends of which are beaten open, somewhat like a brush; it is then ready for the reception of a charge of gunpowder; but the awkward and slovenly manner in which this is introduced, constitutes one of the most imperfect parts of the operation. The gunpowder is poured from a common flask, its quantity being only estimated by guess, so that the requisite proportion is generally exceeded, and not unfrequently to such a degree as to fill the hole. This excess is gradually removed by dipping a wet reed, or perhaps the *swabbing stick* into the powder, and then shaking off the grains which are thus made to adhere to it. But we have yet to recount an inconvenience and loss of still greater magnitude. Suppose the hole, instead of being perpendicular, should be horizontal, or more or less inclined, when it is technically termed a "*back hole;*" in such a case the miner usually prepares upon the spot, a cartridge of paper, cementing together its edges with the tallow of his candle. In this frail machine he encloses the gunpowder, and then with his iron *neele,* or bar, pushes it to the extremity of the hole; it is scarcely necessary

to add that the cartridge is rarely deposited without the loss of some, and frequently the whole of its contents; indeed some miners are so well aware of this difficulty and waste, that, rather than intrust the powder in a cartridge, they deliver it in small quantities at a time, with an iron rod having a concave surface, resembling in some degree the shape of a marrow spoon. But here again another difficulty occurs, for by such means the powder instead of being conveyed to the extremity of the hole, is of necessity, scattered in a train along its sides; to remedy this, the miner has recourse to a most hazardous and frightful expedient, that of thrusting forward the uncovered powder with his iron *tamper!* After the gunpowder has been deposited, clay, or sometimes oakum, is pressed down upon it. A communication must then be secured through the matter which is immediately to be rammed over it, and this is effected by one of two methods, viz. by "*driving the neele,*" (a corruption, I presume, of the word needle), which is an iron skewer about two feet long, having a large eye resembling that of a needle, as represented in plate III, fig. IV; or by introducing into the charge a cylinder composed of quills, and filled with bruised gunpowder tightly rammed together. One of these arrangements having been adopted, the operation of *tamping* next proceeds, which is that of ramming down a quantity of *killas,* pieces of common brick, or

the fragments of any stone which may be at hand, with an iron rammer, called a "*tamper*" or "*tamping bar.*" A solid arch* is thus formed over the charge, which is capable of offering a most powerful resistance to the explosion of the elastic fluids which are generated by its combustion.† After the tamping is finished, the *neele* is withdrawn, by introducing the bar into its eye, and then striking it upwards with a hammer; the cavity thus left, and which

* The influence of pressure in converting angular fragments into solid masses has been curiously illustrated by a process lately practised in France, which is that of converting moistened rubbish into building stone by two or three strokes from a stamping engine.

Birkbeck's Tour through France.

† It has been a problem to discover a method by which the necessity of *tamping* might be rendered unnecessary. In blasting *boulders*, or insulated masses of rock, the pouring in of dry sand upon the charge without any tamping, is sufficient; the Italians blast the Alps in this manner, and the same method is at present practised with effect, at Saint Ives, for the purpose of obtaining stones for the formation of a *breakwater*: I have, however, been informed by some intelligent miners that in hard and solid ground, this is not sufficient, and that in "*back holes*" it is quite inadmissible; I ought, however, to observe, that since the publication of the Report of the Geological Society upon this subject, Mr. Teague, of *Treskerby Mine*, has suggested the practice of driving a plug into the hole, and he states that it has been attended with success.—It sometimes happens that without any compression upon the powder, its combustion will heave its burthen. The explanation which Mr. Oke Millet has given of this circumstance appears to be correct, "the air which

forms a direct communication with the charge, is filled with gunpowder, and a hollow rush or reed, containing powder also, is then inserted, and kindled, or in case of quills having been employed, their contents are ignited by the contact of a snuff of a candle. By such means a sufficient interval elapses for the escape of the miners, before the fire reaches the charge, when the rock is burst asunder. Such is the succession of the different stages of this process, provided all goes on well; but too frequently, an unexpected explosion takes place during the operation, when the unhappy miner is either killed on the spot, deprived of sight, or so mangled as to remain a helpless object of misery for the rest of his days; whilst his wife and children, and perhaps an aged parent dependant upon him, are driven in a state of destitution, to the hard necessity of seeking from charity that pittance which honest industry can no longer supply.

In investigating the causes from which such a catastrophe may arise, it is evident that the concurrence of two circumstances is indispensable; the production of fire, and its trans-

is disengaged from powder acts more powerfully on the sides of holes than on the ends, because more surface of rock is exposed to its action; thus the *tamp* is not blown out, without the separation of the rock: that part of a mortar which contains the powder, forms the segment of an oval, by which contrivance, the air, that is set free from the powder, acts in the most powerful manner."

mission to the mass of gunpowder at the bottom of the hole: this consideration naturally suggests the following arrangement.

I.—*Causes which may elicit Fire.*

1. The collision of the *iron tamping bar* with siliceous or sparry matter,* or with *mundic*, &c.

2. The attrition of the different substances which compose the *tamp* with each other.

3. Driving the iron *neele* with such violence as to strike fire against the bottom of the hole.

4. The friction occasioned by the extraction of the iron *neele*.

5. The vibration and concussion of the extremity of the iron *neele*, principally during the *tamping* of the second layer of rubbish, before it has acquired steadiness and support from the filling up of the hole.

II.—*Causes which occasion a communication with the charge of Gunpowder, and thereby expose it to accidental ignition.*

6. The careless manner in which the powder is scattered about the collar of the hole, or left to adhere to its sides.

* *Spar* is synonimous with *quartz* in the vocabulary of the Cornish miner. *Mundic* is iron or arsenical *pyrites*, which strikes fire with amazing facility, and is generally employed for that purpose by the miner in preference to *quartz*. Pliny mentions this application of *pyrites* very particularly. The term seems to be derived from this quality.

7, The accidental fracture of the cylinder of quills, from the abrasion of the *iron tamper*, or the escape of gunpowder from some one of its joints.*

8. The forcing up a quantity of powder from the body of the charge, by carelessly ramming down too hard and improper rubbish immediately over the clay.

There is also another fertile source of accidental explosion which ought to be noticed, although it has no connexion with any of the above causes, it being solely dependent upon fool-hardiness induced by a desire to save a small quantity of gunpowder, as the following statement given me by an experienced miner will evince; when a hole from any mischance does not explode, it is necessary to remove its contents in order to recharge it, and this is effected with an *iron* scraper, when, in order to avoid spoiling the powder, the miner frequently omits the important precaution of first pouring into it a quantity of water, which would effectually obviate every possibility of an accident.

As the principal causes of accidental explosion thus dispose themselves under two heads,

* I would here observe that such an occurrence is by no means rare, the very operation of *tamping*, by compressing and diminishing the diameter of the quills, necessarily opens the joint immediately above such pressure; for obvious reasons, this will first occur during the second layer of tamping.

so will the measures of safety which are to be adopted for their prevention, viz.—*The introduction of tools which will not strike fire, and the invention of an instrument which will deliver a charge of gunpowder without loss.*

I.—*The introduction of Tools which will not strike fire,*

The necessity of introducing some SAFETY BAR, instead of the fatal tamper in common use, was first suggested to me by my friend Sir Rose Price, more than three years since, his attention having been directed to the subject by the occurrence of several terrible accidents upon one of his farms, in blasting the *boulders* of granite which impeded the progress of its cultivation :—he at that time succeeded in procuring a metallic bar which would not strike fire, although its too great malleability prevented its introduction into general use; at this period, the Geological Society was established, and it was reserved for its members to give a general and public impulse to the investigation which Sir Rose Price had so humanely suggested; their activity, as might be expected, soon awakened a kindred energy in many of the more liberal and intelligent agents, whose zeal upon this occasion cannot be too highly appreciated, but they will receive from the approbation of their own hearts a more satisfactory and solid recompence than from any eulogium which it is in my power to bestow. At the suggestion of John Williams,

Esq. to whom I had sent several bars for trial, and who reported that "they bent, and were unable to stand the work," the extremity of the *tamper* was merely shod with an alloy. Mr. Chenhalls of St. Just, at the same time, had a number constructed upon a similar plan, which he introduced into all the mines over which he had influence, or control, and the principle appeared to answer; it was, however, necessary to ascertain the exact proportion of copper and tin, which would produce the best possible alloy for the purpose; to discover this I made some experiments, and submitted to Mr. Chenhalls different specimens for trial, and I learn from him that the one which answers best is a composition of 86 parts of copper, and 14 of tin.* The SAFETY BAR thus constructed is presented in the plate, fig. III, the alloyed end (*b*), if injured, can easily be replaced for a few pence, the cost of the bar is 1s. 6d. that of the common tamper 1s.

The SAFETY BAR has been in general use for more than twelve months in most of the mines in the western part of the county, and in addition to the evidence already published in the last Annual Report of the Geological Society,

* To those who manufacture the SAFETY BAR, I beg to suggest that they will do well to keep the metals in fusion for some time, and constantly stirred, otherwise the greater part of the *copper* will sink to the bottom, and that of the *tin* rise to the surface, and in consequence there will be found two different alloys, possessing very different properties.

I have the satisfaction to add the following respectable and gratifying testimony of its efficacy.

"*We, the undersigned Mine Agents, have great pleasure in bearing testimony to the security afforded by the introduction of the* SAFETY BAR, *recommended by the Royal Geological Society of Cornwall, against those terrible explosions so frequently attendant upon the use of the iron tampers, and that they are quite unobjectionable in their application, and have been the only ones used in the different mines of which we are respectively the agents; viz. in* BOTALLACK *for* 15 *months, in* BOSWORLAS MOOR *for the same period, in* DING DONG *for ten months, in* PARK NOWETH *for* 14 *months, in* LITTLE BOUNDS *for* 15 *months, and in* HUEL OLDS *for* 13 *months.*" *Dated* 30*th December,* 1816.

Signed,

NICHOLAS GRENFELL, *Botallack.*
THOMAS OATS, *Bosworlas Moor.*
N. WHITE, *Ding Dong.*
JOHN CLEMENS, *Park Noweth.*
JAMES NICHOLAS, *Little Bounds.*
RICHARD BOYENS, *Huel Olds.*

TO JOHN AYRTON PARIS, M. D. &c.

"*We, the undersigned,* SURGEONS *of the principal mines in the parish of St. Just in Penwith, do hereby certify, that since the general introduction of the* SAFETY BAR *into the mines of that district, no accident has occurred from the premature explosion of gunpowder in blasting rocks, and that such accidents did frequently happen when the common iron tamping bar was in use,*" *Penzance, 27th December,* 1816.

Signed, WILLIAM BERRYMAN,
EDWARD COLLINS GIDDY

To DR. PARIS.

It is necessary to state that the *neele* is never used in the mines just alluded to, the fuze being constantly made by quills, and that therefore they have not been exposed to the 3rd, 4th, and 5th causes of explosion.

The IRON NEELE is an instrument no less dangerous in its operation than the *iron tamper,* indeed it appears from the 5th cause of explosion, that during the act of tamping with a SAFETY BAR, an accident is liable to take place if the iron *neele* be employed. In some of the greater mines, a copper *neele* has been for some time in use. Lord Dunstanville, the active and munificent patron of every thing which tends to promote the interest of the county, and the welfare of its population, has, upon this occasion, exerted his influence with considerable effect.

The *needle* is represented in the plate by fig. IV. its eye (*ab*) may be composed of iron, as copper is too ductile for that purpose; its body and point should be *copper*, combined with about a twelfth part of *tin*.

II.—*The introduction of an instrument which will deliver any charge of Gunpowder without loss.*

From what has been already stated with respect to the awkward manner of charging holes with gunpowder, the necessity of some expeditious, economical, and safe method of effecting it, is sufficiently apparent. The instrument which I am about to describe and recommend, completely meets such an intention, and will not only obviate several causes of accidental explosion, but will economize one fifth of all of the gunpowder consumed in the operation of blasting, and thus SAVE to the mining interest of Cornwall a *sum exceeding six thousand pounds* annually! To those who have not considered the subject, such an estimate may appear chimerical, but I am fully prepared to shew that it is a fair approximation; it is well known that the cost of gunpowder used in all the mines of Cornwall, amounts to more than THIRTY THOUSAND POUNDS a year, and I would ask any agent acquainted with the slovenly manner in which it is applied, (taking of course the average of the loss in the charges of perpendicular and inclined holes) whether one

fifth of it, at least, is not entirely wasted?—The idea of delivering gunpowder at the bottom of a hole by means of an instrument capable of adapting its capacity to any given quantity which might be required for a charge, suggested itself to Mr. Chenhalls (whose name I have before mentioned) more than fifteen years ago, but no attempt to convert it to a practical purpose was made, until the Geological Society entered upon the present investigation; Mr. Chenhalls then sent me an instrument, which, after some additions, and farther improvements, is that which I am about to describe, and to which the name of SHIFTING CARTRIDGE has been given. Figures I and II of plate 3, represent a view and section of this instrument: it consists of a copper cylinder (*ab*) two feet in length, and one inch in diameter, containing a moveable rod (*c*) which is graduated in inches, and has affixed to its extremity a leaden plug (*d*), the cap (*g*) is made to take off, in order, at any time, to allow the removal of the rod for cleaning the interior.—MANNER OF USING IT—Draw out the rod as many inches as you require it to deliver of gunpowder, then invert the instrument, fill it, and place a piece of moistened clay upon the mouth of the cylinder; it is now to be inserted into the hole, when, by pressing down the sliding rod, the whole charge is immediately delivered in a mass without any loss; before the instrument is withdrawn, the rod should

be rammed down smartly several times upon the mass of gunpowder.

In charging "BACK HOLES" the only difference which it is necessary to observe in its application is, that the clay should be stuck upon the end of the plug (*d*) previous to the introduction of the powder into the cylinder. When quills are used for a fuze in preference to the *neele,* it will be found advantageous to affix in the cylinder a small tube for their reception, as represented in the plate, by fig. II (*ef*) by which contrivance they may be inserted into the centre, instead of upon the surface of the charge, the result of which is a more instantaneous and consequently a more certain and effective combustion:* thus, suppose the instrument is to carry a charge of four inches, the rod should, in such a case, be pressed down only two inches before the insertion of the quills, and the remaining two after it.

Having thus communicated in detail, the results of an enquiry into the causes of accidental explosion, and described the methods by which so dreadful a calamity may be averted, I may be allowed to hope that I have performed a service of some importance to the county of Cornwall; at all events, I feel that under the circumstances which I have stated, I could not have shrunk from the performance

* It is the application of the same principle that gives superiority to Manton's well known patent breech.

of such a task, without forfeiting every claim to the character, which, of all others, I am most ambitious to sustain; that of a diligent and humane physician, whose duty it is to prevent as well as cure the diseases and accidents to which those around him are more immediately exposed, and by his influence and counsel to correct the habits, and remove the prejudices which are most active in producing them. Let this be received as my reply to those who have censured me for interfering in the concerns of an art, of which I must be entirely ignorant; and if I have ventured to descend into the dark regions of the earth, and have presumed to enquire into the occupation of the intrepid beings who labour in its caverns, it was not without a claim upon the support of a protecting Sibyl, whilst to those perturbed spirits who might oppose my adventure, I was prepared to present this essay as the "DONUM FATALIS VIRGÆ," which should at once appease the fury of their indignation.

[*Here followed a tabular view of ninety-eight cases of accident; the consequences of a large proportion of which were, disability or death.*]

POSTSCRIPT.

As more than twelve months have elapsed since this paperw as read before the Society, and, by a Resolution of the Council, circulated amongst the mine agents in the county, it becomes my duty to state in this publication, that the SAFETY BAR has continued

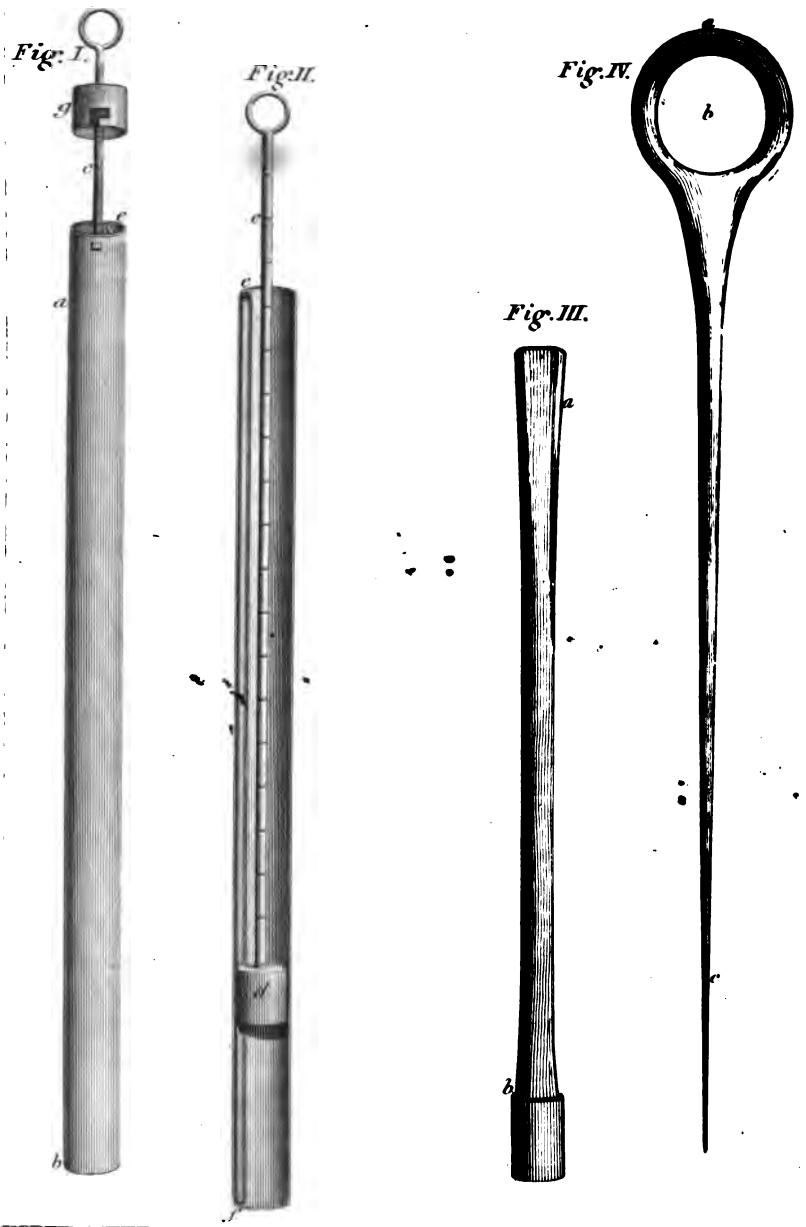
in use in the western mines above enumerated, and that no accident has occurred since its introduction. To what extent it has been adopted in the eastern districts of the county I am not able to state, as I no longer reside in Cornwall, but I indulge a hope that the "iron age is passing away," and that the next volume of this work will announce its final departure.

As an historical document of interest and importance, as a gratifying testimony to the humanity which has ever characterized Cornish Gentlemen, and as a powerful authority in support of the cause I have so zealously advocated, I feel it my duty to place upon record, in this volume, the following Resolution of the Grand Jury of the County of Cornwall, assembled at the last Lent Assizes—Dated, "Grand Jury Chamber, Launceston, March 28, 1817." "*Mr. Justice Abbot having, in his charge, directed the attention of the Grand Jury to the numerous accidents which occur in the mines of Cornwall, from the present methods of blasting rocks with gunpowder, and he having referred to an essay written by Dr. Paris, describing* INSTRUMENTS OF SAFETY, *the success of which, in preventing accidental explosion, has been satisfactorily proved by the testimony contained in the printed Reports of the Council of the Royal Geological Society of Cornwall;* WE, THE GRAND JURY OF THE COUNTY OF CORNWALL, *assembled at the Lent Assizes, at the town of Launceston, feel it to be our duty strongly to recommend the speedy and general introduction of the said* "SAFETY INSTRUMENTS," *to all agents of mines in the said county, and to request the Clergy, Magistrates, and Gentlemen, to give every possible publicity to this Resolution, throughout their respective districts.*"

(Signed)

REGINALD POLE CAREW, *Foreman.*

SAFETY INSTRUMENTS.



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X.—*On Elvan Courses.*

By JOSEPH CARNE, Esq.

MEMBER OF THE SOCIETY.

THE general and indefinite meaning attached to the principal names given by the miners to the stones of most frequent occurrence in the Cornish mines, has been often observed and regretted by mineralogists who have visited Cornwall. For instance—*spar* means not only calcareous spar, and fluor spar, but quartz. *Peach* is either chlorite, or mica, if the latter has a tinge of green. *Flucan* is either a white, or a greenish clay, no matter of what kind. *Growan* is decomposing granite, sienite, or even porphyry. *Cockle* is either schorl, or hornblende. *Killas* is proper grauwacke, or argillaceous shistus, or slate. The indefinite use of this term occasioned, not long since, a paper war between two eminent Scotch mineralogists, both of whom were right

in their application of the term, but incorrect in supposing it to apply to one substance only. Of the word *capel*, it is almost impossible to give a definition, as it refers rather to situation than to substance.

The term *elvan* shares the fate of those already mentioned. It is a stone which frequently occurs in the mines of Cornwall; but so various in its appearance and composition, as well as in its relative situation, and more particularly in its apparent effects on metallic veins or lodes, that whilst in some mines it is regarded as an ill omen, it is hailed in others as the harbinger of riches.

Elvan occurs in Cornwall in inclined strata, which are scarcely horizontal enough to be called beds, and yet this is the only name which can strictly be applied to them. The miners call them channels, or courses; and by the latter of these terms I shall hereafter describe them. Most of the quarry-stone used in building is procured from the top of these courses.

As far as they have been discovered, the elvan courses have the same inclination as the adjoining rocks, and are undoubtedly of the same primary formation: for there appear no marks of a more recent formation in the rocks above the elvan, than in those below it. The lodes also are found to pass through the elvan, in the same manner as through the killas or the granite.

Elvan courses have been most frequently

found in killas: this, however, is no proof that they do not as often occur in granite; but the most productive lodes being in killas, greater search has been made there, and, in consequence, more elvan courses have been discovered.

They have an east and west direction, or they vary but little from those points. They generally underlie rapidly towards the north; much more so than the lodes, which are therefore frequently found to intersect the elvan courses in depth. The point, however, of the greatest importance to us as miners, is, to ascertain the modes in which lodes are affected by coming in contact with elvan courses. These are various.

In the first place—the lode passes through the elvan as through the killas, without any apparent alteration; as in the Weeth Copper Mine in Gwinear, where the elvan course is twenty-four feet wide, and inclines or underlies north, four feet and a half in every fathom. The lode enters the elvan without being disturbed, and continues in size, quality, and hardness, just the same as in the killas. This elvan is hornstone porphyry with quartz.

2ndly. The lode, on entering the elvan, becomes suddenly impoverished, and lessened in size; or, as the miners term it, wrung together. This is the case in Rosewall-hill tin mine in Lelant; where, in a granite country, an elvan course has lately been discovered 150

fathoms under the surface. Its width has not been ascertained. It underlies north-east, about ten feet to a fathom in depth. The lode, which had previously been eighteen inches wide, and rich in tin, quickly dwindled to four inches, and contained very little tin; and even that was of a quality much inferior to what it yielded when in the granite. The elvan here appears to be a close-grained granite, with hornblende and chlorite: very different from the granite of the country, which is of a very large grain,

3rdly. The lode, on entering the elvan, is divided, and becomes much harder than before. In Huel Ann copper mine, in Phillack, the lode, which was presumed to be the same as that of Huel Alfred, presented, whilst in the killas, such favorable appearances, as to make the adventurers confident of possessing a second Huel Alfred. On its entering the elvan, however, their expectations were entirely blasted. The lode was divided into three parts, and became so hard as to oblige the adventurers, after an ineffectual struggle, to relinquish their pursuit. The width of this elvan was never ascertained. It consists principally of very compact chlorite.

4thly. Instances are not unfrequent where the lode, on entering the elvan, not only becomes smaller and less rich, but the elvan becomes mixed with the lode. This is the case in Crenver, Huel Abraham, and Huel Sarah, three adjoining copper mines in Crowan:

In these mines, the elvan course varies in width from one to three fathoms, and underlies in some parts six, and in others even eighteen feet to a fathom in depth, towards the north-west. Its bearing is north-east and south-west. The lode, which is about two feet and a half wide, bears east and west, and underlies south, two feet in every fathom. However rich it may have been in the killas, it becomes small, poor, and often divided into small branches, in the elvan; and the elvan appears to be one of the component parts of the lode. This elvan is a mixture of quartz and mica, and, in some parts, of chlorite.

5thly. In other instances the contrary effects are seen. The lode, on entering the elvan, increases not only in size, but in goodness. Huel Alfred copper mine in Phillack, furnishes a remarkable instance of this kind. The elvan course here is fifty fathoms wide; it bears north-east and south-west, and underlies north-west six feet in every fathom. The lode, which underlies north only two feet, produced some ore whilst in the killas; but on entering the elvan it became much richer, and increasing in goodness as in depth, it at length yielded ore sufficient to give the adventurers a profit of one hundred and forty thousand pounds. Its width in the killas was from six to nine feet, but in the elvan it gradually increased to twenty-four feet. At the depth of 120 fathoms it left the elvan and re-entered the killas;

and from thence it gradually diminished in size, until at the depth of 150 fathoms it was only ten feet wide. It declined also in goodness as soon as it left the elvan. After pursuing it a little deeper, its poverty obliged the adventurers to abandon the concern. Near the surface, this elvan appears rather granitic, but in the deeper parts it is decidedly hornstone porphyry.

6thly. In some mines, the lode, on entering the elvan, becomes not only larger and better, but sends forth small branches which penetrate the elvan on both sides. In the eastern part of Huel Vor tin mine, in the parish of Breage, there are two elvan courses. The northern course, which is the largest, is twenty feet wide, bears north-east and south-west, and underlies north nine feet to a fathom in depth. The lode which underlies north only a foot and a half, was productive in the killas, but much more so in the elvan. In the former, it was two feet wide, but in the latter it increased to five feet, and in some parts branched through the elvan in such a manner as to impregnate the whole of it with tin, and to induce the workmen to take it away even for twenty feet in breadth. The lode is still in the elvan. Near the surface, this elvan appears to consist of decomposed felspar and quartz. A little deeper, hornstone appears. In the deepest part of the south elvan, the hornstone is compact, and in some instances slaty. The latter, it is

supposed, has not been found in any other part of Cornwall. This elvan course has been traced on the surface five miles, from Tolmenor in Breage to Porkellis in Wendron.

7thly. An instance occurs in West Huel Fortune copper mine in Ludgvan, where, in some parts the lode becomes larger and better, and continues entire in the elvan; and in other parts of the same elvan, it is divided into minute branches, called by the miners *strings*, which are still so rich, as to be nearly as valuable as the lode, where it is undivided. This elvan, although decomposed in the higher parts, is, in the deepest level, hornstone porphyry.

Lastly. In Chacewater tin and copper mine in Kenwyn, there are at the surface, two elvan courses a little distant from each other. From their colour, one is called the white, and the other the black elvan. At the depth of about sixty fathoms they unite, and continue in union as deep as they have been seen. The course formed by this union is about six fathoms wide, underlies five feet and half to a fathom in depth, and bears about 20° north of east and south of west. This elvan course, without being at all intersected by, or united to, a lode, is full of small veins of copper ore, which cross it at angles of nearly 45°. Before the union of the two courses, both of them were crossed by these small veins; but after the union the elvan became softer, and the ore richer. That

these rich branches can proceed from no ordinary copper lode, appears from the dipping of the elvan towards the east, where it is completely covered by killas, whereas a lode would have continued through the killas as well as through the elvan.

In the midst of this elvan course, are often discovered small unconnected beds, called by the miners floors, of red elvan, quite distinct from the other, but still intersected by the copper veins. This is an instance of a singular kind; and by favour of Mr. Samuel Moyle, I have procured specimens of the different sorts of elvan, crossed by the veins of copper. The white appears to be decomposed felspa and rquartz: the black, hornstone, with quartz and chlorite: and the red, hornstone, perhaps as fine as Cornwall can produce.

Had there been sufficient time for enquiry, many other mines might be, and perhaps still may be adduced, in which the appearances of the elvan courses would corroborate and illustrate the circumstances already mentioned.

It is presumed, however, that these instances comprize nearly all the different modes in which lodes appear to be affected by elvan courses; except, perhaps, in a few minute and unimportant particulars.

I have purposely said nothing of elvan courses which have no known connexion with metallic veins. It may, however, be stated in general that, particularly in a killas country,

wherever there is a quarry, of which the stone differs from the killas, *there* is certainly an elvan course; and by way of specimen, the surface of one may be seen for some length, at low water, just at the back of Penzance pier.

From the whole we may easily perceive the difficulty, not to say the impossibility, of forming any theory of universal application to elvan courses as connected with lodes.

Should a theory hinge on the courses being more or less horizontal or vertical, it is overthrown by a comparison of those of Huel Vor and Rosewall-hill. In both the inclination is great, and towards the same point; yet in one case the lode becomes richer, whilst in the other it is almost wholly unproductive.

If a theory turn on the consideration whether the elvan course underlies towards the same point as the lode, or towards the opposite point; this is settled by comparing the courses of Rosewall-hill and Crenver. In the former, the elvan course and the lode both underlie towards the north. In Crenver the elvan underlies north, and the lode south, whilst the lodes in both are equally poor.

Should the different component parts of the elvan courses be made the cause of the different circumstances of the lodes, let the Huel Alfred elvan be compared with that of Crenver: they nearly resemble each other: and yet in the former the lode was immensely rich, whilst in the latter it was good for nothing.

Gratifying, therefore, as it would be to scientific men to discover some general law applicable to the apparent effects of elvan courses on lodes, these are, and perhaps will long continue to be, subjects in which the experience and the practical knowledge of the miner are his only guides; and these he has in fact, in this as in many other cases, found far superior to the best merely theoretic rule which could possibly be established.

XI.—*Notes on the Limestone Rocks in the Parish of Veryan.*

By S. J. TRIST, Esq.

MEMBER OF THE SOCIETY.

With an APPENDIX by the Rev. J. ROGERS,

MEMBER OF THE SOCIETY.

THE limestone of Veryan occurs on the coast at Pendower beach, and may thence be traced for one mile and half inland, and is visible at the surface in three different places, nearly at the equal distances, but at different elevations; the most inland being probably a hundred and twenty or thirty feet above the level of the sea. In each instance, it crops out at the brow of a hill, as is attempted to be shewn in the section, (pl. 4), but it no where appears in the vale below; whence it should seem originally to have stretched across

the valleys, but to have been subsequently carried away, together with the accompanying matter, by diluvian action.

In breadth, it extends over a superficies of 350 yards, but alternates to a great degree with an argillaceous schist, the lime itself never exceeding three feet in thickness, and that only in the upper beds of the stratum: it amounts altogether scarcely to one-eighth of the whole mass.

It rises at an angle of 33, but varies from that to above 40; the dip is E. by S. It appears to rest on the primitive districts of the west. The bearing of the three hills in which the limestone is found, is north by east, and the strata of limestone, unlike most other rocks of the neighbourhood, has a conformable position with the formation on which it reposes, as represented by the section.

According to the *analysis* of this lime, as given in Mr. Worgan's "Agricultural View of Cornwall," on the authority of the Rev. Mr. Gregor, a good specimen yields about nine-tenths of carbonate of lime; the component parts being $89\frac{1}{8}$ grains of pure limestone, 10 silex mixed with manganese, and $\frac{7}{8}$ of a grain of oxide of iron.

A ton weight of the stone will produce in quantity nearly twenty single Winchester bushels in *shells*, or *fore-right* lime; to calcine which are required four bushels and a half of culm. A comparative scale of the produce

of the Plymouth and Veryan limestone, I have collected from the publication above alluded to.

PLYMOUTH LIME.			VERYAN LIME.		
Tons of stone, 14½ Single Winchester bushels of culm 56	produce	100 double W. bushels of shells.	Tons of stone, 11 Single Winchester bushels of culm 46	produce	100 double W. bushels of shells.

That is to say, the same quantity of shells is produced from 11 tons of the Veryan stone, as from 14½ of the Plymouth stone, and with ten bushels less of culm.

As a cement, its quality is remarkably good, occasioned, it is thought, by the presence of the two latter ingredients given in the analysis. For manure it is also much valued. Where, however, it has been tried comparatively in this respect with the Plymouth stone, there does not appear to be any difference in their produce.*

We have reason to believe it to be of transition origin. Mr. Buckland identifies it with a lime formation found at an elevation of two miles higher in the Pyrenees. No organic remains have been found in it, except in the instance of a patella, which the quarry-men declared they discovered in the body of the rock, and so nicely was it fitted to it as to make it appear to be coeval with the rock itself. It was afterwards discovered, however, to have been found in a vein of manganese.

* See 'Worgan's Agricultural Survey,' page 129.

stitutes about seven-eights of the whole m wherein the lime is found.

The *floor* on which the lime rests, is argillaceous schist, with veins of mangan In this ground a mine has been wrought wi the last two years, and manganese of good q lity, and in promising abundance, has b found; but of late the work has not been c ried on.

As far as the lime and this formation of ma ganese extend along the beach, there is fou on it a flat stratum of sand and pebbles. This stratum appears occasionally in the st of a black sandstone of the depth of two fee sometimes as a conglomerate of sand, pe bles, &c. amounting to more than ten fe in thickness. Upon it rests the cliff, a mass an argillaceous friable earth, apparently alluvial deposit. How far under the cliff th sand formation extends, there are no immedia means of ascertaining, but it would appear have been thrown up by the sea, previously the lodgment of the incumbent matter, and have been subsequently cemented, probably b the presence of manganese in the neighbou hood.

It is a circumstance worthy of remark, th its appearance abruptly and entirely ceas with the lime on the east, and extends no fu ther than the manganese on the west.

About half a mile further on the west, in th parishes of Tilley and Gerrans, lime again rise

to the surface in two distinct, but not considerable formations, of a coarser grain than the Veryan lime, and with different alternations, though in other respects bearing much the same character. It rises on the coast, but has not being traced inland.

About three miles eastward also, at Polgrane, in the parish of Caerhayes, lime appears under precisely the same circumstances as the Veryan lime, though separated from it by a high and extensive ridge of land that juts into the sea, of which the main rock is greywacké. On a slight examination, this lime formation appeared to be identical with that in Veryan, the intervening land being an incumbent mass of subsequent origin.

APPENDIX.

Observations on the Limestone of Veryan and the neighbouring parishes.

By the REV. JOHN ROGERS,

MEMBER OF THE SOCIETY.

A PAPER on the limestone of the parish of Veryan was presented last year to the Cornwall Geological Society, by Mr. Samuel Trist.—Since that time I have examined most of the places at which it occurs, and beg leave to present to the Society some specimens of the limestone, and of the slate with which it is accompanied; together with a few remarks, in addition to those already made by Mr. Trist.

The furthest point to the west at which I observed the limestone, is below Cargurrel, north-east of Creek Stephen, in the parish of

Gerrans, where I found it dipping east by south, at an angle of about 40 degrees. This lime, as will be seen by the specimen, contains small scales of mica, and in this respect differs from that of Caerhayes and Veryan. Going towards the east, it next occurs on the right side of the road leading from Pendower beach to Gwendra; and again on the right side of the road from Pendower beach to Carne, and from Criddlewell on Pendower beach, to one hundred yards beyond the eastern extremity of the beach. In all these places, as well as in the rock behind the new school near the church, the veins of limestone dip about south-east, at an angle of between 35 and 45 degrees, excepting at the place where it is seen for the last time, about one hundred yards east of Pendower beach, and where the dip is east by north, at an angle of about 40 degrees.—Here the limestone is bounded by clay-slate and greywacké, and by the immense boulders of quartz, mentioned by Mr. Samuel Trist in his observations.

The furthest point to the north at which the limestone is found, is at Polconta. It may be seen there on each side of Fisher's-lane, in veins about twelve or thirteen inches thick, dipping east south-east, at an angle of 45°. and passing from thence down the valley to the sea; it is found again at Badger's-hole, dipping E. S. E. at an angle of 60 degrees: but it has not been seen west of the rivulet. I am told

it has also been found at Caregloose, in the parish of Veryan, but I had not an opportunity of examining that spot.

Limestone exactly resembling that of Veryan is also found at Polgrean, in the parish of Caerhayes, and at several places on each side of the road leading from thence to Portholland. It is found in veins from one to four feet wide, dipping E. S. E. at an angle of 40°.

On the right hand going to Portholland, about a quarter of a mile from thence, is a large mass of greywacké rocks.

Having no instrument with me to measure the dip of the limestone at the several places at which it occurs, I have stated it as nearly as I could judge by the eye.

In conclusion, I have to observe, that limestone occurs also at the following places:—In the parish of South Petherwin, limestone was raised about half a century ago, and has been much used in the neighbourhood of Launceston. (See Worgan's Survey of Cornwall.) This limestone is found half a mile north-east of the church. Limestone has been found in a quarry at Tredinick, a mile below Trengoff, on the banks of the Worlegan river; at Newport, near Launceston; in Tregarla slate-quarry, in the parish of Menhiniot; in the parish of Crantock, between Trevemper and the Gunnel, and likewise at Padstow. I am informed that it has also been found

on an estate belonging to Sir Christopher Hawkins, near the Lizard. Further inquiries will probably discover other places where this valuable mineral is to be found; a subject no less interesting to the landholder and to the farmer, than to the geologist.

XII.—*On the Discovery of Silver in the Mines of Cornwall.*

By JOSEPH CARNE, Esq.

HON. MEM. G.S.L. AND MEMBER OF THE SOCIETY.

[The beginning of this Paper was occupied by a history of Silver Mines in different parts of the world, the publication of which is deferred.]

SILVER extracted from lead has been long known in Cornwall. Carew, in his Survey, says, "Neither hath nature denied silver to Cornwall, and if we may believe our chroniclers reports, who ground themselves upon authentic records, King Edward Ist, and Edward IIId, reaped some good benefit thereof."* This account is echoed both by Norden and Borlase. That the silver here mentioned was extracted

* Survey, page 7.

from lead, may be presumed from the circumstance of miners having been brought from Derbyshire into Cornwall in the reign of Edward First, to work the silver mines.* Now the Derbyshire miners were conversant with lead mines only, and would have been no better than the Cornish for other mines.

Small quantities of lead ore, rich in silver, have, from time immemorial, been found in the tin and copper mines, generally in the cross, or north and south lodes; but the quantity being too small to pay the expense of extracting the silver, it has usually been sold as lead ore.

Some mines near Helston, amongst which were probably Huel Pool, and Huel Rose, were wrought for lead upwards of two hundred and fifty years ago, and the produce was sold merely as lead ore. About eighty years ago, they yielded tolerable profit to the adventurers.

About 1790, Huel Pool was again set at work, and produced lead ore which yielded from thirty to forty ounces of silver per ton, in sufficient quantity to induce the proprietors to erect smelting and testing works for the extraction of the silver; but the expense was so great as to absorb the principal part of the profit which was actually gained by working the mine. A few years therefore terminated this adventure.

Huel Rose was wrought nearly at the same

* Pryce, page 59.

time. Its lead ore yielded sixty ounces of silver per ton; but the quantity not being sufficient to pay the expense, this concern was soon abandoned. The silver was extracted from its ore at the works of Huel Pool.

Dr. Woodward* mentions lead ore, very rich in silver, found at a mine called Guarneck, near Truro, probably that which is now called the Garres. This mine was wrought about 1720, when some of its lead produced one hundred ounces of silver per ton. In 1814 it was again set at work, and continued about two years. During this period it produced eight hundred tons of silver lead ore, containing thirteen parts in twenty of lead, and the lead yielding seventy ounces of silver per ton. The direction of the lode is N. N. E. and S. S. W. Its width is from two to six feet. It is heaved twice by two slides. The ore richest in silver was found between, and adjoining to, these slides, at the depth of about seventy fathoms from the surface. The silver was extracted on the mine.

These are the only modern instances in which silver has been extracted from lead in Cornwall. The silver lead ore found in other mines, after being properly dressed, has generally been sold to Bristol merchants.

The Bishop of Llandaff, in one of his essays, asserts, in substance, that there is no silver

* Vol. 2, page 29.

produced in Great Britain, but what is extracted from lead.* This assertion, at the time when he made it, was probably correct. Silver ore and native silver have, however, since been discovered in Cornwall in many instances, independent of lead.

The first discovery of this kind was made about 1788, in a mine in the parish of Perran Zabuloe, which was, in consequence, dignified with the name of Huel Mexico. This was in a north and south lode, which produced some lead rich in silver; and some fibrous native silver was found in the gossan. The adventurers, however, soon learned that a humbler name would have been more suitable to their mine, as the silver, which was first discovered in the adit, continued a very little way under it.

The next instance occurred in the Herland mine, in the parish of Gwinear. A particular account of this discovery, by the Rev. M. Hitchins, was inserted in the transactions of the Royal Society for 1801. The silver was found in a cross course, or north and south lode, and was richest near the point where this lode intersected the copper lode, particularly where the latter was rich in copper ore. It was discovered in the 90, and continued to the 120 fathoms level. Its extent in length was no where above forty-five feet, but it gradually became poorer as its distance from the copper

* Chem. Essays, vol. 3, page 301.

lode increased. The ore consisted chiefly of vitreous silver ore, arsenicated silver ore, and black oxyd of silver. Some of the latter, called by the miners *goose-dung* ore, contained upwards of 50 per cent. of silver. The specimens of fibrous and capillary native silver have rarely been excelled. The amount of the silver produced in this mine was about £8000. A part of the ore was smelted and tested on the mine, but the cost being considerable, and, perhaps, the proper process not being accurately known, the principal part was sold in Bristol. The miners had a very simple method of assaying this ore. They first calcined it over a kitchen fire, they then placed the calcined ore, with an equal weight of red lead, in a stout iron ladle, and melted it in a smith's forge. The alloy from this melting they afterwards tested.

In Dolcoath, in 1810, some grey silver ore intimately united to cobalt ore, together with a little native silver, were found in the sixty fathoms level in the copper lode, very near a small cross course.

The next discovery of silver ore was made in 1812, in Huel Duchy, near Callington, in a lode inclining to the north-east and south-west, and from one to three feet wide, in which the adventurers were searching for copper. In the adit, silver ore was found in detached lumps, with small bunches of native silver. In the ten fathoms level, there was a regular course

of silver ore, accompanied by native silver, for nearly three fathoms in length, yielding above £200 worth per fathom. This was its richest part. In the twenty fathoms level, some native silver, and bunches of silver ore were found, but the lode had here declined in value. In the next deeper level the silver was exhausted. The ore consisted chiefly of red and grey silver and black oxyd of silver.—The value of the silver produced was about £3000.

Silver has been found in very small quantity in some other mines.

In Huel Alfred, in 1813, some native silver was found, appearing as if plated on the copper ore; but in so small a quantity as not to be worthy of notice on any other occasion.

In 1813 also, silver was discovered in Huel Basset in Illogan, in a cross course. The copper lode here has an east and west direction, and at the twenty-eight fathoms level, (or thirty-eight fathoms from the surface), is two feet and a half wide, and very productive of yellow copper ore. The cross course is about four inches wide, bears south-east and north-west, and intersects the copper lode without heaving it. The silver ore was found in the cross course, at and near the point of intersection; and although very rich whilst crossing the lode, it gradually declined in value as it left the lode, and at the distance of six feet on each side, it almost wholly disappeared.

A specimen of the ore from this mine will shew that, although accompanied by galena, it is a distinct grey silver ore; and, what is a little extraordinary, the galena, although so closely connected with rich silver ore, contains very little silver. No native silver has been found in Huel Basset; but some of the ore yielded six hundred ounces of silver per ton.

Huel Ann, in Phillack, furnishes the next instance. In 1814, a small bunch of blackish grey silver ore, containing a great deal of arsenic and spathose iron, and accompanied by native silver, was found in the sixty-five fathoms level, in an east and west copper lode. In the seventy-five fathoms level, the silver ore appeared in the midst of the copper lode, as a separate lode, from two to five inches wide, between distinct walls of quartz. Some fine specimens of fibrous native silver were found in this level; but these, as well as the ore, proved of very short duration.

The last instance in which silver has been discovered in Cornwall, occurred in Willsworthy mine, (which, indeed, may be said to be rather on the border of Devon) in 1815. The lode here is about twelve inches wide, bearing N.N.E. and S.S.W. and underlies two feet and a half per fathom to the south. In the ten fathoms level, a vein of white and amethystine quartz divided the lode: between this vein of quartz and the lower, or northern wall of the lode, was found a vein of rich

arsenical cobalt ore, combined with native capillary silver, in a ferruginous matrix, from three to six inches wide. The space between the vein of quartz and the higher, or southern wall of the lode, was occupied by a vein of rich yellow copper ore, from six to nine inches wide. The silver continued about two fathoms in length. The copper was not so soon exhausted. The specimens of native silver from this mine have eclipsed all that have ever before been found in Cornwall, both in size and beauty.

The mines of Cornwall in which silver has been found, have been, without exception, in killas or argillaceous schistus.

The circumstances in which silver has been generally discovered in Cornwall, should induce the miners to pay more attention to the component parts of cross courses, or north and south lodes, than they have been hitherto accustomed to bestow on them. The Herland mine, already mentioned, furnishes a case in proof of the utility of a stricter examination of these lodes. When the principal cross course was discovered to be rich in silver, search was made in several others for this precious metal, and the result proved its existence in a neighbouring course, called, from its reddish colour, the Rusty Cross Course. It would certainly be wise to subject the contents of every cross course which may be discovered

the avarice which had tempted mankind to abandon the agricultural pursuits of their forefathers, and penetrate into the bowels of the earth in search of the noble metals.*

But the most eloquent example of this philosophical declamation, is to be found in the works of Seneca. This writer is giving an instance of the great depth and extent of the Thracian mines before the age of Philip, which affords him an occasion to rejoice that in former times, mankind were no less depraved than in his own.†

* "Imus in viscera ejus," exclaims Pliny, "et in sede manium opes quærimus, tanquam parùm benignâ fertilique, quaquà secatur." Again, "Mens ad inane evolans reputet quæ deindè futura sit finis seculis omnibus exhauriendi eam: quousquè penetratura avaritia." L. XXXIII.

† "Illi quoque majores nostri, quos celebramus laudibus, quibus dissimiles querimur nos esse, spe ducti, montes cæciderunt, et supra lucrum sub ruina steterunt. Ante Philippum Macedonem reges fuere, qui pecuniam in altissimis usque latebris sequerentur, et relicto spiritu libero, in illos se dimitterent specus, in quos nullum noctium dierumque perveniret discrimen, et a tergo lucem relinqueret. Quæ tanta spes fuit? Quæ tanta necessitas hominem ad sidera erectum incurvavit, et defodit, et in fundum telluris intimæ mersit, ut erueret aurum, non minore periculo quærendum, quam possidendum? Propter hoc cuniculos egit, et circa, prædam lutulentam incertamque raptavit, oblitus dierum, oblitus naturæ melioris à qua se avertit. Nulli ergo mortuo terra tam gravis est, quam istis supra quos avaritia urgens terrarum pondus injecit, quibus abstulit cœlum, quos in imo, ubi illud malum virus latitat, infodit. Illo descendere ausi

Some of my readers, perhaps, will feel inclined to ask who this Stoical philosopher was; who pronounces a long and animated invective against the pursuits of subterraneous wealth. He was the richest man in the Roman empire, and so far from practising what he here professes, was remarkable for the luxury and magnificence in which he lived; and, in short, for the value which he set upon all the good things of this world. Nor was Pliny, who was also a very wealthy man, more disposed to renounce the luxuries of life, or the means of acquiring them.

Setting aside the above awkward circumstances in the private life of these eminent philosophers, which, undoubtedly, have the effect of diminishing our respect for their doctrine; let us figure to ourselves what would be their surprize and indignation, could they be permitted to view the audacious attempts that have been made in our days, to pursue the mineral dæmon into the most hidden recesses of the earth, and to make the elements of fire and water subservient to our avarice.

And yet, unless we suppose them to belong to the class of infallible philosophers, how much would their surprize be heightened and

sunt, ubi novam rerum positionem, terrarumque pendentium habitus, ventosque per cœcum inane experirentur, et aquarum in illis fluentium horridos fontes, et altam perpetuamque noctem. Deinde cùm ista fecerint, inferos metuunt. Nat. Quæst. L. v. cap. xv.

their indignation lowered, when they perceived that all our mining operations were carried on by free men and not by slaves, by voluntary, not by compulsatory labour.

On a review of the improvements which have taken place in our machinery within the last forty years, I am inclined to think that the spirit of mining enterprize, to which they have imparted so much animation, will soon assume a character of still greater audacity. Perhaps when the veins are exhausted, which lie within the boundary of our sea-girt peninsula, we shall turn our attention to those which extend in the same direction beneath the bed of the ocean; nor, when we consider the increasing depth of our mines, can that period be very distant. Our submarine works will then form a new epoch in the history of mining, and by calling forth still greater exertions of skill and industry, demonstrate in a more striking manner, the powers of the human intellect.

The attempts that have been made to realize this project, shew that it is by no means a chimerical one. There are some coal-mines at Whitehaven which have long been extended under the sea, and there is an instance, I believe, of a lode at Huel Cock, near the Lands-end, which was for some time pursued in that direction, until the ore having been worked out too greedily in the roof of the mine,

fears were entertained that the sea would break through and put an end to the operations.

But by far the most remarkable enterprize of this kind, was formed about thirty years ago, by a poor man of the parish of Breage. It was an attempt, not literally indeed, but in effect, to sink a mine in the sea itself, and to carry on these operations, surrounded by water.

There is something so grand in the conception of this undertaking, when the feeble means are considered, by which it was to be accomplished, that I have long thought it entitled to a very honourable place in the annals of Cornish mining. I shall therefore communicate all the particulars of this singular mine, which were collected by me when it was still open in the year 1791, and that the narrative may not want a classical interest, I shall prefix to it some account of whatever has been attempted in this way by the Greeks and Romans.

I find only two examples in ancient history (and they are not very obvious to notice) of mines wrought in or under the bottom of the sea. One of these is mentioned by Pausanias, who, speaking of the temple at Delphi, observes, "Near the votive offering of the Tarentines, is the treasury of the Siphnians. It was built upon the following occasion. Their isle produced mines of gold. Apollo commanded them to dedicate a tenth part of their

produce to the temple at Delphi. They built a treasury and remitted a tenth; but when through avarice they had ceased to do this, the inundations of the sea destroyed the mines and caused them to disappear."*

There is nothing in this story which may not be accounted for by natural causes. The mines were at first very productive: they were wrought by degrees to a greater depth and with less profit: at length, when the Siphnians were tempted to pursue the veins even under the sea, that might very naturally happen, which is here related; the sea broke through the weak partition, and wholly put an end to the operations of the miners.†

Tournefort, who visited the island of Siphnos,

* PHOSIC, SIVE LIB. X, CAP. XI.

† Suidas relates the same story, v. Σιφνιοι. We are informed by Herodotus, that Siphnos abounded in mines of gold and silver to such a degree, that from a tenth of the revenue which was derived from them, the Siphnians offered a treasure at Delphi that might be compared with the richest in the temple there, L. III. CAP. LVII. The period in which the mines of Siphnos were in this flourishing state was, according to the Chronology of Larcher, about 525 years A. C. but they must have been on the decline not long afterwards, for the Siphnians sent only one vessel of fifty oars to the battle of Salamis; and in the time of Demosthenes they were become fully as insignificant as the inhabitants of any of the Cyclades, vide Demosth. Περι Συντάξεως quoted by Larcher. Strabo does not even notice the former existence of these mines, so completely were they forgotten in the time of Augustus.

in the year 1700, says, "that the ore of lead abounds there, but as for the mines of gold and silver, the inhabitants scarcely knew where they were. In order to shew us, however, what were principally considered as such, they conducted us to the sea shore, near a ruined chapel, called Aios Sosti, where we saw the entrance of the mine only, not being able to proceed farther on account of the darkness, and the difficulty of access."

The same views led me to visit the island of Siphnos in the year 1787, but the natives, who were justly apprehensive of the consequences of exciting the financial avarice of the Porte, contrived to oppose so many difficulties to my researches, as obliged me to relinquish the attempt.

A second instance of a submarine mine is mentioned (although indirectly, as well as the preceding), in those extracts from the works of Aristotle, which are known under the title of Περι θαυμασιων Ακουσματων*

The same circumstance is repeated by another collector of the wonders of Nature, Anti-

* Δημόνησος η Καρχηδονίων νῆσος, απο Δημονήσου του πρώτου εργασαμένου, τὴν επωνυμίαν ἔιληφεν. ἔχει δὲ ὁ τόπος κυανοῦν το μέταλλον, και χρυσοκόλλης. ταύτης δ'ἡ κτλλίστη πρὸς χρυσίον ἐυρίσκει τιμήν. καὶ γὰρ φάρμακον οφθαλμῶν ἐστιν. ἔστι δὲ αυτόθι χαλκος κολυμβητὴς εν δυῖν οργυιᾶις της θαλάσσῆς. Here the χαλκος κολυμβήτης is generally understood to mean copper which is collected by diving.

The χαλκος κολυμβητης reminds us of the expressions sea-coal, stream-tin, bay-salt.

gonus Carystius, who, however, substitutes Delus for Demonesus; a mistake which probably arose from the celebrity of Delus for its works in brass. "Antiquissima æris gloria Deliaco fuit." PLIN. L. 34. Both these compilations give us Καρχηδονιων, which, according to the opinion of some eminent critics,* ought to be Χαλκηδονίων, the Chalcedonians on the Bosphorus.†

But all doubt is removed by the discovery of the vestiges of these mines on a small island near the shore of Chalcedon, which still retains the name of Kalki. Gyllius mentions it in his work de Bosporo Thracio.‡

* Salmasius ad Solin. p. 137. Bochart Can. 1. 26. Holstenius de Pinedo, and Berkelius ad Stephanum, and others. Vide Bechmann's edition of the two works.

† Hesychius is more correct and explicit on this subject "Δημονησιος χαλκός. δύο εισὶ πρὸς πῶ. Βυζαντίω νῆσοι, καινῆ μεν Δημόνησοι λεγόμεναι, ιδιά δέ διαλλάττουσι, ἡ μὲν γὰρ Χαλκῖτις, ἡ δὲ Πιτοῦσα."

‡ "Verum ut clarius perspiciatur Demonesus eadem insula esse, quæ [Chalcitis, ut nunc sunt, ostendam vestigia metallorum et situm insulæ, quæ tribus verticibus seu collibus intumescit; unus vergit ad Aquilonem, alter ad occasum, tertius ad orientem. Insulæ latus meridianum est præceps et abruptum in rupes, excepto sinu, admittente recessum maris portuosum, quoquoversus patentem paulo plus stadio, tutum ab omni vento, excipio Austrum. Circa hunc sinum existunt aggeres scrobium, pleni ruderibus cœruleis, rejectis ex effossione æris et chrysocollæ, et cærulei, atque inter ipsa rudera collegi eximium cœruleum et absolutam chrysocollam. Quodsi

In the year 1794 I had an opportunity of visiting this small island, which, although hilly, is no where more than twenty fathoms above the level of the sea. I found in the situation here described, prodigious heaps of mining rubbish, in every part of which the green and blue oxydes of copper were observable. From the magnitude of these heaps, compared with the little elevation of the ground above the sea, it was evident that the greater part of the mining operations must have been carried on below the sea level, and as the rubbish lay close to the shore, it may fairly be presumed that the works were extended under the sea. As for the popular notion of the copper having been obtained by diving, that may have arisen from the actual discovery of some native copper towards the surface of the veins below water, a circumstance, which, in Cornwall, would not be thought extraordinary.*

vadum maris ibi effoderetur, sine dubitatione inveniretur aurum illud ab Aristotele laudatum. Aggeres scrobium sunt in radicibus vallis supra sinum jam dictum eminentis et secantis insulam a mari meridiano ad mare septemtrionale."

I suspect that Gyllius has been led into this mistake by Stephanus Byzantinus, who renders the expression of Aristotle η καλλιστη προς χρυσιον πυρισκει τιμην præstantissima chrysocolla auro contra venditur by χρυσιον πυρισκειαι τιμιον.

* These mines had ceased to be worked in the time of Pliny, who, describing the different sorts of Smaragdus (our emerald) observes, "Carchedonii (Chalcedonii) nescio an

Such are the obscure and imperfect notices, which, I have been able to discover, of submarine mining in ancient times, and the instances are few, because mines are generally situated at a distance from the sea. I shall now proceed to give some account of the submarine mine near Penzance, which, about twenty years ago, so much attracted the public attention, and to which the name of *Wherry* Mine was given.

The first attempts to work this singular mine are said to have been made towards the beginning of the last century, when many small veins of tin being observed to cross a rocky shoal, which is exposed to view at low water; some persons were induced to make it an object of mining adventure. How long they persevered in this difficult enterprize, and what were the mechanical aids of which they availed themselves, is not known; but the works, after being sunk to the depth of a very few fathoms in the rock, were finally abandoned.

About the year 1778, a poor miner of the parish of Breage, whose name was Thomas Curtis, had the boldness to renew the attempt. But before I proceed to speak of his plan of operations, and the success which attended them, it will be necessary to give my readers

in totum exoleverint, *postquam metalla æris ibi defecerint*, et semper viles fuere minimique." Theophratus speaks of the same smaragdi, "ἐν τῇ νήσῳ τῇ ἐπικειμένῃ Καρχηδόνι."

some idea of the natural obstacles which he encountered.

The distance of the shoal from the neighbouring beach at high water, is about 120 fathoms, and this, in consequence of the shallowness of the beach, is not materially lessened at low water. It is calculated that the surface of the rock is covered about ten months in twelve, and that the depth of water on it at spring tides is nineteen feet. The prevailing winds occasion a very great surf here even in summer, but in winter the sea bursts over the rock in such a manner, as to render all attempts to carry on mining operations unavailing.

Such were the difficulties which a poor individual had to surmount, whose whole capital perhaps was not ten pounds. As the work could be prosecuted only during the short period of time when the rock appeared above water, (a period which was still farther abridged by the necessity of previously emptying the excavation), three summers were consumed in sinking the pump shaft, a work of mere bodily labour. The use of machinery then became practicable, and a frame of boards being applied to the mouth of the shaft, it was cemented to the rock by pitch and oakum, made water tight in the same way, and carried up to a sufficient height above the highest spring tide. To support this boarded turret, which was twenty feet high above the rock, and two feet

one inch square, against the violence of the surge, eight stout bars of iron were applied in an inclined direction to the sides, four of them below, and four of an extraordinary length and thickness above. A platform of boards was then lashed round the top of the turret, supported by four poles, which were firmly connected with these rods. Lastly, upon this platform was fixed a wins for four men.

It was thought that the miners would thus be enabled to pursue their operations at all times, even during the winter months, whenever the weather was not particularly unfavourable; but as soon as the excavation was carried to some extent in a lateral direction, this was found to be impossible, for the sea-water penetrated through the fissures of the rock, and in proportion as the workings became enlarged, the labour of raising it to the mouth of the shaft increased. Their predecessors, as well as themselves, had carried on their excavations too near the surface, which not only made the rock more permeable, but less able to resist the immense pressure of water at high tide, so that it became necessary to support it with large timbers. To add to this disappointment, it was found impossible to prevent the water from forcing its way through the shaft during the winter months, or, on account of the swell and surf, to remove the tin stone from the rock to the beach opposite.

The whole winter, therefore, was a period of

inaction, and it was not before April that the regular working of the mine could be resumed. Nevertheless, the short interval which was still allowed for labour below ground, sufficed most richly to reward the bold and persevering projector, and to give his mine the reputation of a very profitable adventure.

Whether he ever felt a conviction of the possibility of removing so many natural obstacles to his complete success, I know not, although there is reason to suppose that he did; for when I asked his opinion of the scheme of erecting a light-house on the tremendous Wolf-rock, he professed his belief in its practicability, but suggested as far preferable, the blowing up of the entire rock, which he readily engaged to do for a proper remuneration.

The following was the state of Huel Wherry in the autumn of 1791:

Depth of the pump, shaft, and of the workings, four fathoms two feet.

Breadth of the workings, eighteen feet.

The roof was worked away in some places to the thickness of three feet.

Twelve men were employed for two hours at the wins in hauling the water, while six men were teaming from the bottoms into the sump. The men worked on the rock six hours afterwards: in all, eight hours.

Thirty sacks of tin-stone were broken on an average every tide; and ten men, in the space

of six months, working about one-tenth of that time, broke about £600 worth.

There is something very remarkable in the natural history of this mine. The workings were confined to a course or channel of elvan, about eighteen feet in breadth, which runs N.W. and S. E. and underlies one foot and a half in a fathom to the S.W. It is discoverable on the beach at half tide.

Besides the small veins of tin which ran through this rock, its whole mass was impregnated with tin to such a degree, as to be worth the expense of raising; fifteen feet of the eighteen, which composed the breadth of the elvan, producing 1600 of "white tin" in 1000 sacks, and another foot as much as one cwt. of "white tin" in every sack.

On a close inspection of the mass in which the tin is thus abundantly dispersed, the grains appear of a crystalline transparency, and so equal in size, and regularly distributed, as to form, as it were, one of the constituent parts of the porphyry. The term *stannified granite*, which has been applied to it, is not, therefore, improper. It is said to have been the first tinstone that was ever burnt in Cornwall before it was sent to the stamping-mill, a common lime-kiln having been erected for that purpose, which was found to answer completely. The object of this operation was to render the texture of the stone more friable.

In September, 1792, a friend (Mr. D. Gilbert) wrote to me as follows:—"The course of stanniferous porphyry, near Penzance, (the Wherry) promises to make a very great mine. There are indications of the tin being continued to a great extent in both directions, and the bottoms are growing longer, and remain rich. A house near the green, built with fragments of this stone, which were, probably, picked up on the shore, or broken from the top of the rock, is, I hear, to be pulled down and rebuilt with other stone, for the sake of its tin. An adventurer told me that three thousand pounds worth of tin has been raised from this extraordinary mine in the course of the present summer."

In a subsequent letter, the same friend informed me—"A steam engine is erecting on the green opposite, and they are constructing a wooden bridge from thence to the rock, to serve as a communication, till the engine shaft has been sunk sufficiently deep, and a drift worked out to the mine, as a stage for supporting the sliding, or rather hanging rods." See plate I.

The bridge, thus constructed, answered also the purpose of conveying the *ore* and *deads* to the shore. In this manner the mine was conducted, and ore to the amount of seventy thousand pounds was raised from it. Nor indeed were its treasures exhausted at its close,

which was as romantic as its commencement. An American vessel broke from its anchorage in Gwavas Lake, and striking against the stage, demolished the machinery, and thus put an end to an adventure, which, both in ingenuity and success, was probably never equalled in any country.

XIV.—*On some remarkable Phænomena attending the Lodes of Polgooth Tin Mine.*

By JOHN HAWKINS, Esq. F.R.S. &c. &c.

MEMBER OF THE SOCIETY.

THE object which I have in view, in the following communication, is to point out to the notice of geologists, a case of rather unusual occurrence in the natural history of our mineral veins, the explanation of which will shew the practical importance of these enquiries.

I shall, therefore, confine myself to the statement of such phænomena as were either observed by myself, or were communicated to me in 1791, by the very intelligent director of the mine, Captain Phillips; in the hope that others, who may have the means of doing it, will supply that information which is here deficient; for it is probable that, as the mine continued

open some years after I visited it, the further extension of the works under-ground may have enabled the miners to ascertain many facts which were at that time undetermined, and to make other important discoveries.

And here I must express the regret which I feel, in common with so many others, that no records are preserved of all those natural phænomena which occur to the notice of our miners in the progress of their operations. I regret it not only on account of the loss which the science of geology sustains by its omission, but because I believe it has materially affected the stability of our whole mining system; for, if it be true, that old mines are often re-opened, in reliance on some vague traditional reports of their former productiveness, which generally prove fallacious; how desirable it would be to prevent all this waste of capital, and to reserve it for less hazardous speculations! There is, moreover, a great analogy between the phænomena of lodes in the same district, which serves to guide the miner in any new adventure; but how can he fully avail himself of this advantage without having recourse to some better authority? If we consider it in another point of view, the loss which science sustains by this omission, will appear to be incalculable; for the progress of our mining operations is of necessity so slow, that ages scarcely suffice to develope all the circumstances which characterize the mineral veins of a particular district,

and if these circumstances be not committed to writing as they occur, how seldom can they be accurately reported, and how often must they be wholly forgotten.

The importance therefore of recording these observations, must be admitted; and what a length of time is requisite in most instances to complete them, will be evident from the following account of Polgooth, which, although one of the oldest mines of the county, was not sufficiently explored in the year 1791, to enable me, or even the director of the mine, to decide upon some points of the greatest interest.

A few words, perhaps, may be necessary in this place, to justify the use which I have adopted of our provincial terms. I must observe then, that every mining country has a technical language of its own, which is more or less expressive, and for which it would be difficult to find an equivalent in the received idioms. The question then is simply this—shall we retain the use of this language, or attempt to explain ourselves, and at the best very imperfectly, in a language which is more generally understood? The patriotic views which were proposed by the institution of this Society, must, in my opinion, decide us to adopt the former of these alternatives; nor can there be a doubt, should a more general diffusion of mining ideas render it expedient, that these terms would soon cease to be provincial.

It is well known that Polgooth has been one

of the most productive mines in the county, and it will appear from what follows, to be no less interesting in a scientific point of view.

The country (to use the language of our miners) is composed of killas; the beds of which dip in an angle of about 20° to the W. S. W.

The principal lode here, which has been so productive of tin at different periods in the course of the last century, runs E. and W. by the compass, and has been traced to a very great extent in that direction. (See plate V.)

Its general underlie is to the north; the only exception to this being in a small space of ground west of the old engine, where, at the depth of ten fathoms from the surface, the lode underlies a little to the south, for the space of several fathoms in length, and a few in depth: the cause of which is attributed to some hard ground in the northern wall of the lode.

With respect to the degree of its underlie, as the lode is composed almost wholly of small veins which drop in, as it were, on both sides, the leader itself being so small that it frequently disappears, there is scarcely a possibility of ascertaining it with any degree of precision. It may be assumed, however, in a general way, at six inches in a fathom, and it amounts to twelve inches at the place where it meets the New Glands lode.

Its breadth upon the whole, is very inconsiderable, contracting frequently to six inches

and seldom exceeding twelve, but there is a spot near the Old Glands shaft and Burn's, where the lode is so much enlarged by the numerous branches that fall into it, as to amount to from ten to fourteen feet. It has been observed, that some of these branches strike out again in the space of a few fathoms, but others continue incorporated with the lode to a much greater extent. They are not inaptly called *feeders*, for they seldom fail to make good bunches of tin at the point of their coincidence.

The lode, or to speak with more precision, its leader, contains much spar (quartz) which here and there encloses tin, accompanied by peach (chlorite); but almost all the tin is found either composing the small fissures which run through the killas on the sides of the lode, or immediately in contact with the wall of the lode: in each case there is an abundant intermixture of peach, and often a small portion of yellow mundic. Even the killas itself is sometimes impregnated with tin on the sides of the fissures. It is the breadth of these fissures collectively, added to that of the spar leader, which is usually called here the bigness of the lode; although that term is sometimes confined to the single vein of ore which runs through the *caple*.

This lode, which, for the sake of distinction, is called Polgooth lode, intersects several others, which run in a north-west and south-

eastern direction, and have been very productive of tin.

The opposite parts of one of these intersected lodes, in consequence of a circumstance which once occasioned some doubt of their identity, have obtained two different names, the northern being called Polyer, the southern Screeds.

The direction of this intersected lode is N.N.W. and S.S.E. by the compass, and its underlie is east nearly four feet in a fathom.

The average breadth of Polyer is between six and seven feet, that of Screeds is from three feet and a half to four feet, and its substance, which is in general very solid, is composed of spar and peach. It is remarkable that some *horses of killas,* which are three or four fathoms in depth, and two or three feet in breadth, are found inclosed in this lode.

Screeds, or the southern division, has been heaved by Polgooth lode about fifteen feet to the right, or on the side of the greater angle, and, together with it, a lode of considerable size, which diverges from that point about twenty-two degrees to the eastward.

This lode is called St. Martyn's, and its corresponding portion is said to have been once explored at a spot called Phillis's Old Chear Shaft, where it is said to have exhibited such symptoms of poverty as to have discouraged all farther attempts to pursue it. There is, however, a general belief, or rather prejudice,

among the miners here, of its being incorporated with Polyer, although the difference in the direction of these two lodes warrants a contrary inference.

The direction of St. Martyn's is nearly N.W. and S.E. by the compass. It underlies nearly six feet in a fathom to the N.E. and its general breadth is about four feet, although in some places it amounts to twelve.

The contents of this lode are chiefly spar, mixed in some situations with tin and peach.

It has been observed in respect to Screeds and St. Martyn's lodes, that this tin is always found in the hard substance of the lode, and not in the adjoining killas.

Polgooth lode intersects another, the southern portion of which is called New Glands.

The direction of this lode is N.W. by N.: its underlie is one foot and a half in a fathom to the north, and its breadth is generally one foot and a half.

The northern portion of New Glands, which has likewise a different name from its corresponding half, has been tried principally at very shallow levels; where, in consequence, as it is supposed, of some very hard ground which composes the northern wall of Polgooth lode, it is split into small branches, which are in some places almost imperceptible. At the depth, however, of ninety-six fathoms, it exhibits its usual character. It is generally supposed to be heaved, like the preceding, by

Polgooth lode. On the other hand, there is a cross course near Burn's shaft, running north and south, and underlying about one foot and a half in a fathom to the west, which heaves Polgooth lode itself about one foot to the left. This course is said to be about ten inches in breadth, and it is composed of copper ore and mundic.

Southward of the New Glands is another lode, called Vanvean, which is distant in one spot as much as ninety fathoms from Polgooth lode, and points one degree of the compass towards it westward. The true direction, therefore, of Vanvean, is west by north by the compass. Its underlie is nearly the same as that of New Glands. Its general bigness may be estimated at one foot, and it is composed of spar and peach.

Both New Glands and Vanvean intersect and heave Screeds and St. Martyn's lodes.

At the distance of sixty fathoms farther to the south, and of one hundred and fifty fathoms from Polgooth lode, occurs a large course or quarry of elvan, which points with a still greater degree of inclination towards Polgooth lode as it proceeds westward.

This porphyritic dyke, as it may be called, which is known here simply by the name of elvan, has a very considerable underlie to the north (six feet in a fathom) and falls into Vanvean lode at the forty-eighth fathom level, in-

tersecting it horizontally after the manner of a slide, and occasioning a start.

Elvan has been traced to the depth of seventy-six fathoms under the adit, and it has a regular breadth of seven fathoms. In its progress eastward, it cuts sharply through Screeds lode, and heaves it fifteen feet on the side of the smaller angle.

If we follow the elvan still farther in the same direction, we shall come to the point of its intersection with St. Martyn's, where some phænomena occur, to which I must particularly direct the reader's attention. This point is at the distance of 320 fathoms from the spot, where Screeds and St. Martyn's are each intersected by Polgooth lode.

Here then at the forty-five fathoms level, both the Elvan and St. Martyn's lode are intersected by an upright flookan, which runs nearly in an angle of 30° to the direction of the former. The consequence of this has been a very considerable and complex heave on the left, or on the side of the smaller angle.

A plan of this remarkable heave, and of the relative situations of the separated lodes, which was communicated to me by one of the directors of the mine, is here inserted in the general drawing of the lodes. The distance from A to B is sixteen fathoms, and B is supposed to be the corresponding part of St. Martyn's lode. It is plain, however, that this cannot be

the case, because, although we have innumerable instances of lodes being intersected and heaved, there is not one of their being shifted, *i. e.* misplaced, as to the order of their succession, in the manner here supposed. For whether A had previously cut through F, or was itself intersected, its corresponding part would be found on the right of the Elvan, not on the left of it. In the former case it would be between C and D, in the latter at D. But the reasons for believing it to be at D, are, I think, conclusive, and they are as follow. We see that Screeds and St. Martyn's lodes are both intersected by New Glands and Vanvean, and again that Vanvean itself is intersected in its underlie by the elvan. The elvan, therefore, is of more recent formation than either of the four lodes here mentioned, and, accordingly, we see it passing through Screeds, and without doubt it would be seen to pass in the same manner through St. Martyn's, were it not for the interruption which it subsequently experienced from the flookan. Again, as the heave of Screeds lode was to the left, we must conclude that that of St. Martyn's lode was in the same direction, and consequently must look for its corresponding part at D, where, perhaps, it has by this time been discovered.

As for B, which, from the circumstance of its running in the same direction as St. Martyn's lode, has been mistaken for D; its correspond-

ing lode will be found on the north wall of the flookan, at the same distance from A eastward as it lies from E eastward. Lastly, the southern continuation of B is C. The continuation of Screeds in like manner must be looked for at G.

XV.—*Remarks on the Salt Mines of Wielitska in Poland, and of Salzburg in Germany.*

By JOHN HENRY VIVIAN, Esq. M.G.S.L.
MEMBER OF THE SOCIETY.

Communicated in a letter to John Ayrton Paris, M.D. &c.

IN my last communication I gave you some account of the arsenic and cobalt works of Saxony and Bohemia; I now send you an extract from my journal, containing remarks on the celebrated salt mines of Wielitska in Poland, which I visited in the summer of 1815, and also on those of Salzburg, which I had seen in the preceding fall, in passing from Vienna into Italy, through the Tyrol.

On Friday, the 30th of June, I called upon Mr. De Lille, the director of the Wielitska mines, by appointment, having been favoured with a letter of introduction to him by Mr. De Draverujak, the President of the Board of Mines at Schemnitz, in Upper Hungary. I

was received with the greastest civility, and his son was so obliging as to accompany me in my under-ground excursion.

Salt mines are a sight, in the description of which, travellers are generally found to indulge their fancies. I have not myself met with any account of those of Wielitska, but I understand that some flowery descriptions of them have been published, and I must admit, there are few cases in which they would be more excusable.

These mines are situated at the foot of the Carpathian mountains, on the north side, and about eight miles from the city of Cracow. It is proved, from authentic documents, that they have been worked upwards of 600 years.

The mouth of the principal shaft is in the town of Wielitska, and the workings extend on all sides of it, in length about 800 fathoms, and in width about 400 fathoms; the greatest depth is 120 fathoms.

The descent into these mines is extremely commodious. For the first thirty fathoms it is by a spacious stair-case carried down the sides of a shaft, at the bottom of which is an object that attracts general attention, and is really worthy of admiration. It is a spacious chapel, with an altar, and figures of Monks performing mass, with divers other figures in the attitude of prayer, and monuments, crucifixes, pillars, &c. against its sides, all hewn out of the solid

salt, and of such antiquity that no tradition records when it was executed.

I was particularly astonished by the uncommon dryness and hardness that prevailed, and this I found generally the case throughout the mine. From the chapel the descent is mostly by steps hewn out of the salt, or accompanying rock. The levels are on a magnificent scale, perfectly straight and regular; eight or nine feet in height, and nearly as many in width. The blocks and barrels of salt lying about and piled away in them, give them the appearance of store-cellars.

On reaching the bottom of the mine, another object pointed out to travellers as being worthy of observation, is the *lake*, a considerable basin of water with a large excavation over it; the salt bed having been very steep in that part. A boat is kept on this water for the purpose of traversing it.

On the occasion of the visit of the Emperor of Russia, when on his way to the Congress in 1814, the mine was illuminated, and in this part there was music and fire-works; the effect of the whole, from the accounts, must have been very magnificent.

Some of the excavations in the upper salt bed are several fathoms square, and are certainly very striking objects; and the miner will not fail to be attracted by their method of supporting the ground by means of immense solid trees, piled horizontally in cross layers,

but this practice is now, in a great measure, done away, by leaving wherever they conveniently can, arches of salt, which are not affected by the weather, as the accompanying marl is.

The salt is of the description called rock salt. It occurs in beds which run east and west, and in general dip to the southward. In this, however, they vary, being much disordered.

They distinguish three beds, having each their peculiar character, and varying in the quality of their salt.

These beds are known by the names of

The Grünsalz bed;

The Spyzasalz bed; and

The Szybickersalz bed.

The Upper or Greensalt bed, is so much broken and disordered as to form a sort of *stockwerk*, the parts being separated from each other. The general form of its parts is nearly round, that is, of equal dimensions; some of them are many fathoms in diameter, and present considerable excavations. I observed, on an inspection of the plans at the mine, that all these parts have nearly the same inclination. These separated pieces, lying above and by the side of each other, are first found at the depth of twenty or twenty-five fathoms under the surface, and descend to that of about sixty or sixty-five.

The quantity of salt obtained from this bed

has been immense, as the excavations on it fully testify. It is, however, not pure in quality, being much intermixed with earthy matter. If the earths with which it is mixed are not very perceptible, no notice is taken of them, but the whole is broken and sold together; if, on the other hand, the mass is very foul, it is left under-ground. It takes its name of grünsalz or green salt, from its being of a greenish colour.

The middle or *spyzasalz* bed, is less disordered than the grünsalz; its parts are much flatter, and not so considerable in depth in proportion to their other dimensions. The thickness may be about five or six fathoms. The salt from it is of a greyish colour; it is of a finer grain, and much more pure than the green salt.

The lower or *szybickersalz* bed, has considerable undulations, but is not broken. It is composed of two or three separate layers, which may be three or four fathoms in thickness. Its salt is for the most part perfectly clear and pure; some blue gypsum occasionally breaks with it.

The strata above these salt beds are chiefly clay or loam, with a thin bed of sand: the mass between them is a marl, varying in colour and hardness. In this shells sometimes occur; and near the lower bed some beautiful clear crystals of salt, from one to four inches square, are occasionally found.

The mode of working these beds, is as follows:—The green salt bed is so much disordered, that levels are driven in different directions, for the discovery of its parts or fragments. These levels are very spacious, and are driven with great regularity. I remarked a singular mode of carrying them through the salt body where it occurred. The centre of the fore-breast was left standing, and a groove, of perhaps two feet in depth, was made round it with the pick. Thus freed on all sides, a large hole was bored in the centre, and the whole was thrown down at one blast. The blocks of salt prepared for sale, are obtained by making perpendicular cuts in the body of salt with the pick, as high as the bed will admit of, or as may be convenient for the miners to work; these cuts are then intersected by others carried horizontally, and the square pieces into which the pillars are thus divided, are detached by cutting a little at the back with the pick and then driving in wedges. They are then hewn into the form required.

Two sizes of these blocks were pointed out to me, the one or the other was obtained as the purity of the salt body would admit of.

The largest, called *balvanen*, are said to weigh four or five cwt. each, and are of a long cylindrical form, for the convenience of transport.

The others, called *formatsteine*, are long four sided pieces, weighing from 90 to 100 lbs. each.

These blocks are exported without cases, and are so solid as not to be affected by the weather. The small that falls in cutting and dressing them is packed in casks, but the blocks are preferred by merchants, as the casks are liable to be opened and pilfered by the carriers.

The salt blocks and casks are drawn through the under-ground levels or galleries, by horses, of which I was told there were about thirty in the mine.

From the depth of thirty fathoms they are raised to the surface through a perpendicular shaft, by a singular old whim, worked by six horses. It consists of a large horizontal wheel with two rows of teeth, which work an upright one attached to the cage.

The blocks are slung in cords; the weight raised at a time was said to be from 25 to 30 cwt.

There is only one footway into the mine, having a grating and small building over it. The men are strictly searched on leaving it. They all work by the job, and receive a part of their earnings in corn.

The water of the mine is drawn to the surface in sacks made of hides. It is so fully saturated with salt, that it deposits crystals as it flows through the landers in the mine. Stalactitical masses are also formed from its droppings. The crystals are perfect cubes; I observed them in several places prettily grouped.

Such is the apparently inexhaustible store of the rock salt, that the mine water, which is by no means inconsiderable in quantity, is allowed to run to waste at the surface.

A handsome evaporating house was built during the time that these mines belonged to the Saxon and Austrian governments jointly, and fitted up with pans and every thing necessary; but it was soon found that the salt obtained by this process was much dearer, owing to the cost of the fuel required, than the rock salt from the mine: and as there was no scarcity of the latter to be apprehended for some centuries, the plan was abandoned, and the building is useless. Should they ever be obliged to resort to the process of evaporation, it is not likely that there will be any deficiency of saturated water, as from the quantity of impure salt from the green salt bed that is left underground, it may easily be produced by conveying fresh water into the mine.

These mines belong to the Emperor of Austria; they are situated in the province of West Gallicia, which fell to his lot at the partition of Poland at the peace of 1809, after the battles of Aspern and Wagram. Part of West Gallicia was taken from Austria, and annexed to the Duchy of Warsaw, which belonged to the King of Saxony. The mines, from that time till the peace of Paris, belonged jointly to the two governments, and a Saxon Commissary resided at Wielitska.

The Wielitska mines, I was told, produce at present about 25,000 tons of salt annually, but that double this quantity might be raised if it could be disposed of. It was observed, that by attempting to keep the price too high, their sales had of late been much curtailed, as the Liverpool salt had found its way to Warsaw and the north of Poland. A contract, I was informed, had just been entered into with the Emperor of Russia for the supply of his new kingdom with 25,000 tons a year for five years, at eleven Polish florins per cwt., which is about equal to £6 per ton.

There are likewise salt mines at Bochnia, about fifteen miles from Wielitska, but they are not so productive as the latter; the beds are much steeper, and not so thick.

The salt is sent to Cracow, and from thence down the Vistula.

In Mr. de Lill's collection, I remarked some specimens of native sulphur from a bed near Cracow.

On the Salt Mines of Salzburg.

On the 26th of November, 1814, I visited, in company with a friend, the salt mines of Hallein, distant about eight miles from the town of Salzburg, and the principal of the district. From the town of Hallein we ascended a steep mountain over a commodious road, formed by the King of Bavaria, to the church of Dürren-

berg. The view from this elevated situation of the Vale of Salzburg, and the bold limestone rocks of the Unterberg and surrounding country, certainly the most picturesque in Germany, is most delightful.

In a cottage near the church, we were furnished with dresses, and when equipped à la Saxonne, entered the mine by a shallow adit, having its name Freudenberger Stolln engraved over the entrance.

The first part of this level was elliptically arched, and six feet and a half in height from the channel for the water. As we entered the salt country, its sides and roof were strongly timbered, which the salt is said to preserve; it still continued lofty and commodious. After thus travelling at our ease between three and four hundred fathoms, we arrived at the top of an inclined shaft, which we descended in a most singular and ludicrous manner. About the centre of the flat wall of the shaft, two smooth pieces of wood, like the sides of a ladder, were laid solid, with some planks on the outside of each, and a small narrow footway of sunken steps between. Over the platform on one side was a strong rope, on the other a rail, for the convenience of those that ascend. The descent was performed sitting, or rather reclining on the centre pieces, the legs and feet resting on the platform; and by holding the rope in the right hand, which was protected by a string glove, we were enabled to slide down at

the pace that was most agreeable. This may be regulated by the position of the body; ours was very rapid, and but for the caution of our attendant, who led the way, would, no doubt, have been still more so. It is, however, by no means dangerous, as by planting the left heel in the steps of the footway, the pace may instantly be stopped. Several persons may thus descend in a string, the one resting on the shoulders of the other.

In this manner we descended through three shafts, upwards of one hundred and fifty fathoms.

The underlie, or angle of inclination of these shafts, was not the same in all. That of the first was said to be 43 degrees; the second, at an angle of 49°, we found to be so steep that we were obliged to throw our bodies completely back, to prevent ourselves from going too fast. About the middle of the third flight we turned out to visit one of the kammern or chambers, in which the fresh water, conveyed into the mine from the surface, is inclosed for the purpose of dissolving the salt which is much intermixed with clay. In our way we passed two or three basso relievos of Bishops of Salzburg, and a tablet to commemorate the visit of the Emperor. These are in stone, and were conveyed there from the surface. The salt rock was not sufficiently solid to admit of sculpture.

The chamber was six feet and a half high,

and from six to seven hundred fathoms in circumference. The largest is said to exceed a thousand fathoms.

The salt stone is so intermixed with clay and gypsum, as to form quite a breccia. As it cannot be obtained sufficiently pure for use, these chambers are filled with fresh water from the surface, and carefully closed up, when in the course of five or six weeks the water becomes fully saturated. It is then drawn off as it may be required by the boiling houses, which are in the town of Hallein, and the salt is obtained in the usual way by evaporation.

The salt stone being dissolved, the clay falls to the bottom of the chamber, which is well stamped, after the water is drawn off, and a fresh floor formed. Thus the chambers continue to rise through the salt country a few inches at each filling. There are in all thirty-four chambers in the mine, but few only are full at the same time, as it requires a considerable time to fill them with water, and to clear and prepare them after they have been used.

The salt country, I was informed, might be from two hundred and fifty to three hundred fathoms in depth.

There are seventeen levels driven from the surface into the mine at different heights, for the convenience of supplying it with fresh water, and taking it off when saturated.

Our journey out of the mine by one of these adits, was equally pleasant and amusing with

our descent. Seated across a long plank placed on four wheels, and having a swing beam beneath it for the legs to rest on, we travelled at a rapid pace upwards of 1200 fathoms through the level; the carriage running on a wooden rail road, was drawn by a man, two boys assisting him by pushing behind. The level was in excellent repair, and well timbered; about four feet wide at the bottom, tapering to two feet at the top.

The director of the Hallein works informed me that their annual produce amounted to about 15,000 tons, and that the other salt works in the country at Berchtesgaden, Rosenheim, &c. might yield together about double this quantity; the price I was told was four florins per cwt. and of this one half might be clear profit; thus yielding a considerable revenue to the sovereign. Some of the salt stone is sold in the country in its native state, for the use of horses and cattle, particularly that from the Berchtesgaden mine, which is the most solid. The greater part of the prepared salt is sent into the Austrian dominions by means of the River Salza, which is rendered navigable at Hallein, and communicates with the Danube. A part is likewise sent overland to Bavaria, and into the Tyrol.

At the moment of our visit, we found the utmost anxiety in the mine agents and directors as to their future fate. The Province of Salzburg, which was formerly an independent

Bishopric, having been transferred at the peace of Amiens from Austria to Bavaria, the Austrian agents, who had then been dismissed, were now looking out for the country to be restored to their sovereign by the decision of Congress, and to their being replaced in their situations.

XVI.—*Observations on the Geological structure of Cornwall, with a view to trace its connexion with, and influence upon its Agricultural Œconomy, and to establish a rational system of Improvement by the scientific application of Mineral Manure.*

By JOHN AYRTON PARIS, M.D. F.L.S. &c.

HONORARY MEMBER OF THE SOCIETY.

THE fabulous and romantic age of geology may be said to have passed away; its disciples, no longer engaged in the support of whimsical theories, direct all their attention to the discovery of facts, and to their application to purposes of extensive utility. The present æra of geology may therefore, with much truth, be compared to that of its kindred pursuit, chemistry, when in the dawn of the sixteenth century it escaped for ever the trammels of alchemy, and assumed the rank and importance of an inductive science. The parallel

may be carried still farther; for it must be confessed, that the benefits incidentally derived by chemistry from the visionary researches of the alchemists, and those which have been conferred upon the science of geology by the zealous but mistaken pursuits of its earlier disciples, are equally numerous, and alike important; the happy allusion of Lord Bacon to the fable of Æsop, respecting the former, may, with much truth and force, be applied to the latter. "They are like those husbandmen, who, in searching for a treasure supposed to be hidden in their land, have, by turning up and pulverizing the soil, rendered it fertile."

Amongst the number of useful facts which have been thus brought to light, few perhaps, in the science of geology are more striking, none undoubtedly more useful, than those connected with the discovery of a certain regular order in the occurrence and association of the different mineral beds and strata, which form the surface of the globe, and whose disintegration and decomposition have given rise to the loose covering or soil, from which vegetation springs, and by which it is nourished, supported, and perpetuated.

There is certainly no district in the British Empire where the natural relations between the varieties of soil and the subjacent rocks can be more easily discovered and traced, or more effectually investigated, than the county of

Cornwall; and no where can the information, which such an enquiry can afford, be more immediately and successfully applied for the improvement of waste lands, and the general advancement of agricultural science.

As we advance from a primitive to an alluvial district, the relations to which I have alluded, become gradually less distinct and apparent, and are ultimately lost in the confused complication of the soil itself, and in that general obscurity which necessarily envelopes every object in a state of decomposition: we can, therefore, only hope to succeed in such an investigation by a patient and laborious examination of a primitive country, after which we may be enabled to extend our enquiries with advantage through those districts which are more completely covered with soil, and obscured by luxuriant vegetation; as the eye gazing upon a beautiful statue, traces the outline of the limbs, and the swelling contour of its form, through the flowing draperies which invest it.

The construction of a geological map of a county like Cornwall, if viewed only as it regards the subject of this memoir, must be anticipated with considerable interest; and should the labours of this Society terminate with the completion of this great desideratum, it will have to boast that it has presented one of the greatest gifts which agriculture can receive from science. It would not only point out the

connexion between the varieties of soil and the subjacent rocks, but it would explain the local circumstances which might be friendly or hostile to their improvement, and direct the agriculturist to the different mineral substances associated together in their vicinity, and which might contain principles capable of extending their fertility, or of correcting and modifying the causes upon which their poverty or barrenness may depend.

The county of Cornwall may be said to consist of four primary rocks, each of which, by decomposition, gives origin to a peculiar soil, distinct in its nature and characters, and requiring an appropriate system of cultivation and improvement. They all however agree in one essential particular—their earthy combinations are few and simple; the great object of art is therefore to extend and multiply them, and thereby to encrease and diversify their chemical and mechanical agencies. In alluvial districts the very contrary obtains, for nature has already mixed and compounded the different particles of rocks in every proportion and in every manner, and has therefore left but little to be effected by the suggestions of science, or the resources of art.

The principal rocks of which the county of Cornwall consists, are granite, schist, hornblende rocks, and serpentine. Beds of limestone, dykes of porphyry, veins of quartz, and those of other minerals, will also claim a por-

tion of our attention, inasmuch as they effect an influence upon the soils beneath which they occur.

Granite forms the skeleton of the county, upon which all the other formations repose. The soil to which its disintegration gives origin, is provincially termed a *growan soil*; it occupies a very considerable area of the peninsula of Cornwall, constituting no less than three hundred thousand acres, one half of which is unenclosed waste land, affording a scanty pasturage for a miserable breed of sheep and goats; but which, by drainage, and judicious cultivation, might, without doubt, be much improved. The other portion of *growan* land is endowed with various degrees of fertility, and capability of improvement, in different districts, or even in different spots in the same district; a fact which seems to have an intimate connexion with the nature of the granitic substratum, and consequently to admit of elucidation from the enquiries of geology.

That the texture of granite, and the proportion of its component parts, had a considerable influence upon the degree of fertility of the superincumbent soil, I was led to believe by a bare inspection of specimens brought from fertile and barren districts. Mr. Tyacke, of Godolphin, has, at my request, furnished the Society with some striking specimens in confirmation of this fact, and I have had an oppor-

tunity of adding others. Mr. E. Giddy has likewise contributed to the collection in farther illustration of the views which are offered in this memoir. It is hardly necessary to remark, that granite consists of three substances in the state of mechanical admixture, viz. *felspar*, *mica*, and *quartz*, the first and last of which being essentially different in chemical composition, are necessarily so in their agricultural influence. *Felspar* is capable of being, in part, resolved into aluminous earth, and includes, moreover, several elements which have been discovered by experience to be highly congenial to the process of vegetation: quartz, on the contrary, has a powerful tendency to resist disintegration, and even when it is decomposed, it is reduced only into siliceous particles. The nature of felspar varies also very considerably in different kinds of granite; it occurs sometimes in an earthy form, is easily pulverized, and emits, when breathed upon, a strong smell of aluminous earth; at other times it is met with in a hard, compact, and less earthy state, not easily yielding to the action of air and moisture. In some felspar the proportion of its siliceous greatly exceeds that of its aluminous elements, and in others again magnesia forms a constituent part.

The relative proportion of mica appears also to have some influence, and where this ingredient occurs in granite in very considerable

abundance, it is generally indicative of a light and poor soil. I have detected the presence of magnesia in several of such soils, but I should rather attribute their barrenness to the circumstance of a large proportion of mica being frequently associated with a considerable quantity of quartz in the granite of Cornwall. There are, besides, incidental ingredients in granite, which must be taken into account, such, for instance, as iron, whose presence not only disposes the rock to a rapid decomposition, but it may subsequently become a useful element in the soil itself.

It would appear from these views that the value of a *growan soil* will bear a relation to the proportion of felspar in the subjacent granite: it is therefore a circumstance which should be always examined by the scientific agriculturist, who wishes to form a correct estimate of the capabilities of any *growan* district. Upon an investigation of many of the more fertile parts of Cornwall, this fact is very strikingly illustrated; it will be found that in such districts the quantity of felspar in the granite varies from 70 to 90 per cent. and that it possesses also the earthy texture which so greatly accelerates its decomposition; this is one of the mineralogical circumstances which will explain the unusual fertility of the *growan* soils in the parishes of Saint Burian, Sennen, and Saint Leven, and which are let, upon an average, at

the rent of £4 per acre;* on the other hand, let the geologist, in passing over the dreary and barren moors which occupy the centre of the county, collect specimens of its granite, and they will be found to offer a striking contrast to those of more fruitful districts; many other instances might be mentioned, but the geologist will have no difficulty in multiplying them. The Islands of Scilly are very fertile, a circumstance depending upon the large proportion of felspar and iron, which enters into the composition of the granite, and the consequent rapidity with which its decomposition proceeds. Guernsey consists of *gneiss* abounding in felspar, its soil is accordingly fertile; whereas the granitic parts of Norway are distinguished for the abundance of quartz, and we therefore find that their superincumbent soils are sterile. Von Buch confirms the truth of this report; he observes, in his travels through that country, that "in the fruitful clay-slate the ground yields twelve times the amount of the seed, whereas on the rocky granite soil it hardly repays the diligence and pains bestowed on its cultivation."

* These soils produce large crops of corn of every kind, of red wheat from 40 to 45 Winchester bushels per acre, of prime barley from 45 to 60, 70, and even 90 have been produced; in these estimates, collected by Mr. Worgan in his agricultural survey, it must be remembered that the Cornish exceeds the statute acre nearly in the ratio of six to five.

In granitic countries, the frequent recurrence of rain is likewise a powerful cause of fertility, and in this respect the climate of Cornwall is certainly highly congenial; there is a popular adage, well known to the members of the Society, that "*the land of Cornwall will bear a shower every week day, and two upon a Sunday.*" This, like most of our popular sayings, is founded in valuable observation and experience, and serves to record an opinion sanctioned by the universal consent of successive generations; the philosophical explanation of the fact is, that the shallowness of the soil, and the large proportion of siliceous matter entering into its composition, together with the nature of its rocky substratum, render a constant supply of moisture indispensable for its fertility. This is one of the numerous instances of intelligence and design which nature displays in connecting the wants and necessities of the different parts of creation, with the power and means of supplying them; thus in primitive countries like Cornwall, the soil necessarily requires moisture, and we perceive that the cause which occasions, at the same time, supplies this want; for the rocks, elevated above the surface, solicit a tribute from every passing cloud, whilst in alluvial and flat districts, where the soil is rich, deep, and retentive of moisture, the clouds float undisturbed over the plains, and the country frequently enjoys that long and uninterrupted series of dry weather, which

is so congenial and necessary to its fertility. Linnæus observes, that the plants which chiefly grow upon the summits of mountains, are rarely found in any other situation, except in marshes, because the clouds, arrested in their progress by such elevations, keep the air in a state of perpetual moisture, somewhat resembling that of the fogs in meadows and marshes; in exemplification of this fact, the locality of *parnassia palustris* immediately suggests itself to our notice.

As a general rule, it may be stated that in order to obtain the greatest fertility, the proportion of siliceous matter in a soil ought to be encreased according to the quantity of rain that falls, or rather perhaps to the frequency of its recurrence; for it is evident that one of the principal effects of this element is, to diminish in the soil its capacity for moisture; we accordingly find that in the rainy climate of Turin, the most prolific soil has from 77 to 80 per cent. of siliceous earth, and from 9 to 14 of calcareous, whereas in the neighbourhood of Paris, where there is much less rain, the silex bears only the proportion of from 26 to 50 per cent. in the most fertile parts.

Let the agriculturists of Cornwall, if there be any who regret the frequent recurrence of rain, hail with gladness the golden showers that fill their granaries with corn, and clothe the pastures with perpetual verdure.

"Not such as wintry storms on mortals shed,
Oppressing life, but lovely, gentle, kind,
And full of every hope, and every joy,
The wish of Nature."——

To return from this digression, I would observe that the essential character of a *growan soil* may be stated to be a peculiar unsusceptibility to all external agents, and an inaptitude in its internal composition, to those chemical changes with which fertility seems to be connected: I have examined a great number of such soils, and have rarely met with much soluble matter in their composition. These observations, however, apply with different degrees of force to different districts, according to the value of the soil, and to the extent of judicious improvement which it may have undergone. As a rule for the amelioration of a *growan* soil, it may be recommended, as a general principle, to encrease the number of its elements, and consequently to extend their affinities. The Cornish code of agricultural improvement may be very shortly expressed, Mix, Combine, and Multiply Manures. In the treatment of a growan soil, in particular, the manures cannot be too complicated, and those of an animal and vegetable nature should be always previously mixed with clay, decomposed slate, or other argillaceous substances, with which they may contract an intimate union, and by such means be more securely

preserved in the land to which they are applied.

My friend, John Scobell, Esq. of Nancealverne, who has a considerable estate in the western part of Cornwall, communicated to me a singular practice which the farmers in his neighbourhood pursue with evident advantage, which is that of actually dressing their incorrigible land with the comminuted fragments of decomposing granite. Strange and enigmatical as this may appear to the agriculturist who has not studied the subject of mineral manures, to the mineralogist it is a fact, capable of easy and satisfactory explanation: the *growan*, or decomposed granite, contains, as I have before stated, large quantities of felspar, and therefore of alumina, with small quantities of alkali. I have made several experiments in order to detect the presence of an alkaline element; and, by treating the pulverized substance with sulphuric acid, I have succeeded in producing a crop of alum crystals. Upon the same principle the application of decomposing slate proves a valuable manure for *growan* lands, since it contains alumina in very great quantities, and is therefore capable of imparting to them that tenacity of which siliceous soils are destitute. This intermixture of soils, or of decomposing rocks capable of producing them, where one kind of earth is either redundant or deficient, has been most successfully practised in other counties. Mr. Bakewell, in his

"Introduction to Geology," observes, that part of Lancashire is situated on the *red sand rock*, which being principally composed of siliceous earth and the oxyd of iron, forms of itself very unproductive land; but that, fortunately, in many situations, it contains detached beds of calcareous marle, by the application of which it is converted into a most fertile soil. Mr. Brande has also observed in the General Remarks upon the Soils of Great Britain, which are appended to his descriptive catalogue of the minerals of the Royal Institution, that experience and science have greatly improved the advantages to be derived from the proximity of different soils to each other; and that there can be no better illustration of the utility of an intimate acquaintance with the relation of the different strata, than the amelioration of the Suffolk sands, which, by the proper application of a substratum of a shelly marle, provincially termed "*crag*," have been changed from a parched and useless heath to arable and productive land. A most interesting illustration of these views seems to be presented in the extraordinary fact which I have discovered in the county of Cornwall, respecting the encreased fertility which characterizes soils that are superincumbent upon the junctions of rocks. The most superficial observer may easily satisfy himself of the truth of this fact; indeed the line of junction between the granite and slate formations, may, in many

parts, be traced by the eye alone through tracts of cultivation, from the remarkable fertility which attends it. It may be defined a *zone of fertility*, since both the *growan* and *slaty* soils become mutually enriched as they approach each other: numerous are the examples which might be adduced in confirmation of this fact; the following, however, as being readily accessible to investigation, are particularly noticed. The most valuable part of the estate of Trengwainton, the seat of Sir Rose Price, lies upon the junction of slate and granite; this line may be traced to Madron church, and from thence round the Mount's Bay, in the direction of which we shall invariably find the superincumbent soil distinguished for its superior fertility. It is probably worth notice, that all the villas around this beautiful bay are placed upon the junction of rocks. Where the *hornblende formation* intrudes itself, the fertility of the land is still farther encreased, as may be seen on the valuable estates of Castle Horneck, and Trereiffe, as I shall hereafter have occasion to notice, when I treat of *hornblende* soils. The zone of fertility may be also seen well characterized on the line of junction between granite and slate at Penrhyn, and on that extending from Chyoon on the acclivity of Paul-hill, to Mousehole, in the Mount's Bay; this latter instance attracted the attention of Mr. Worgan, who, in his general view of the agriculture of Cornwall,

notices this district as one highly fertile, and as being famous for producing two crops of potatoes in one year. On Saint Michael's Mount the geologist will also discover an example of the fertilizing influence which the junction of slate and granite exerts upon the superincumbent soil; the beautiful carpet of herbage covering the south-eastern base of this singular spot, is a feature which instantly strikes the attention of the stranger. To these examples I may add another, which I have very lately discovered: I was requested by my friend Mr. Pendarves, to examine whether any geological arrangements could explain the cause of a particular line in his estate of Pendarves, being more fertile than the neighbouring lands; upon tracing the direction of the granite and slate formations, we soon discovered that this line of superior fertility, was superincumbent upon the junction of these rocks. In making a tour through the county of Cornwall, you will frequently hear the farmer speaking of a vein of rich land; I have generally found upon enquiry, that this is no other than the *zone of fertility* superincumbent on a junction. During the summer of 1816, I made a geological excursion around the peninsula of the Lizard, and farther opportunities were thus afforded me of confirming my opinions upon many points connected with the objects of this memoir, and of collecting illustrations from a district highly interesting,

and, but little explored. In proceeding from the church of Constantine* to Mawnan, I was fortunately accompanied by a very intelligent farmer of that district, who informed me that in the former parish the *killas* and *growan* lands as they came together were much improved in quality, and that they were mutually encreased as much as one third in value; he also stated that the crops upon this "*rich vein*" were much earlier. Some time since I mentioned these results of my enquiry to Mr. Whidby, the ingenious and scientific director of the "Breakwater" in Plymouth Sound, and he informed me that the same encrease of fertility, as far at least as he had noticed, was certainly evident upon the different junctions in the neighbourhood of Plymouth. I have not had any opportunities of extending the enquiry into other counties, but I should hope that the publication of these short and imperfect notices may awaken the attention of more able and diligent geologists, and that a mass of facts may be ultimately collected which will lead to a full and satisfactory explanation of this interesting phenomenon; at present, I confess I feel much difficulty in accomplishing it. That

* This spot deserves the attention of the geologist, for in a quarry may be seen the best, and, perhaps, the only well defined *gneiss*, in the county of Cornwall; it was pointed out to me by a zealous member of our Society, the Rev. John Rogers, of Mawnan.

the intermixture of the decomposed parts of these different rocks, is one grand cause to which we are to look for explanation I am willing to admit, but I cannot help suspecting that future enquiries will also discover that there are other equally important causes involved in the explanation; bold as the conjecture may appear, it is by no means unphilosophical to suppose that some galvanic influence may exert a powerful agency, perhaps by accelerating decompositions, and promoting in the elements of the superincumbent soils those various changes which are essential to luxuriant vegetation.

In alluding to the silent, secret, and corrosive agency of the galvanic influence, I cannot resist the opportunity of directing the attention of the Society to an interesting illustration of its effects, which has been lately afforded by the rapid, and for awhile inexplicable, decay of the flood gates in the port of Hayle, a circumstance which has been discovered to depend entirely upon the contact of iron and copper bolts and braces, introduced into the different parts of the frame work.

Slaty soils, or those produced by the decomposition of *slate* or *schistus*, are, generally speaking, much more productive than the *growan* soils which I have described, although, like the latter, they vary considerably in their degree of fertility; a fact which depends upon a number of circumstances, amongst which may

be noticed, the inclination, or dip of the strata —the chemical composition of the rock—the number and size of the quartzose veins that intersect it, &c. Where the schistose strata have a considerable underlie, the superincumbent soils are usually light, hungry, and ungrateful; the soluble ingredients are washed away, and the manure which is applied, passes off through the fissures of the strata, and consequently produces only a transient benefit to the land. That the composition and texture of the slate rock exerts also an influence upon the fertility of the superincumbent soil, is a fact equally evident; where, for instance, its fracture is siliceous, and its texture resists disintegration, we may be generally led to the inference, that such a district is inferior in fertility. I have seen well marked examples of the relative value of slaty soils depending upon such a circumstance; for instance, on the north-eastern side of Godolphin Hill, the schistose soil exceeds in value at least one-third that upon the northern side; upon examining the slaty substratum, it will appear that the former is friable, and almost earthy, whereas the latter is siliceous and brittle. I have generally observed, that where the slate has a disposition to shiver into thin laminæ, the superincumbent soil is poor. The improvement of such districts is to be effected by the application of the same principles as those

recommended for the amelioration of *growan* lands.

The next soil which presents itself to our notice, is that superincumbent upon the varieties of hornblende rocks; these, of course, vary as much as the nature of the rock which produces them; they all, however, exhibit the same characteristic peculiarities. I shall, therefore, for the sake of perspicuity, comprehend them under the general name of *hornblende soil.*

All the varieties of this soil are more complicated in their composition than those which have been already described, and they universally constitute the richest and most fertile parts of the county; if, upon taking an estate, the farmer discovers any blocks of this rock, which is known by the provincial name of *dun* or *iron-stone,* he may congratulate himself upon the circumstance, for it is generally an omen of the land's fertility, or, at least, of its capability of improvement. Notwithstanding the density and hardness of this rock, it decomposes most rapidly, apparently in consequence of the disposition which its ferruginous elements possess, to combine with oxygen; this fact is seen in the ochreous appearance of the different faces of the stone, and which has bestowed upon it the popular name of *iron-stone*: experience has also at length taught the inhabitants a fact which theory could easily have anticipated, that this stone, notwithstanding its hardness, is

by no means a durable material for the repair of public roads. The colour of this soil has a reddish hue from the presence of iron; it contains in its composition a considerable portion of aluminous earth, and more vegetable matter than in the other soils; this depends upon a greater disposition in the earthy elements to combine with it; I have also found many saline compounds; indeed, it would seem that the internal changes which take place in these soils, are more numerous and rapid than in the others before mentioned: the iron, no doubt, contributes essentially to these changes. I have already in my paper upon the "Recent Sandstone of Cornwall," alluded to the important agencies of this mineral body, and the present enquiry is capable of affording a farther illustration of its extensive influence in the œconomy of the earth's surface; amongst the saline bodies which abound in hornblende soils, is *sulphate of lime,* probably the result of a play of affinities between the calcareous sand with which it is manured, and the salts of iron which are derived from the decomposition of the *pyrites* with which hornblende rocks so universally abound. *Nitrate of potass* is also a salt, which very frequently occurs in abundance; in the fertile lands at Alverton, near Penzance, it may, in dry weather, be collected in great quantities, in a state of efflorescence; how far the presence of this substance influences the fertility of the soil, I am not

prepared to say, but Dr. Clarke has an observation in his travels in Russia, which is well worthy of notice. "The earth is strongly impregnated with nitrate of potass in all the environs of Woronetz, and it is to the presence of this mineral that the extraordinary fertility of the Ukraine has been attributed. The whole country, south of Tula, abounds with it; insomuch that it sometimes effloresces on the soil, and several fabrics for extracting it have been established."

There is no part of the county where the superior fertility of hornblende soils may not be witnessed: in the Mount's Bay, the fact is most striking. The shores of this beautiful bay, in the vicinity of Penzance, consist principally of hornblende rock and slate, and their fertility is not exceeded in any part of the kingdom; a belt of land around this town, consisting of one thousand acres, produces a rent of £10,000 per annum! All hornblende soils, however, are not equally fertile, as I have before stated, a fact which depends upon the structure of the rock, and seems to offer another point of analogy between hornblende rocks and basalt, and lava. M. Cordier* has lately examined this last substance, with a view to explain why some currents of lava remain always sterile, while others are speedily covered

* In a memoir read before the Royal Institute of France on the origin of basalt and wacke rocks.

with the finest vegetation; and he found that this difference depended upon the degree of vitrification which the lava had undergone.

Where the hornblende rock has a considerable proportion of felspar in its composition, its fertilizing influence is further encreased, as is seen in the sienitic formation of St. Keverne. The lands between the church of this parish and Coverac Cove, constitute one of the most extraordinary districts in the kingdom, presenting a rare combination of rudeness and fertility; gigantic boulders, and fragments of sienite, lie scattered in all directions, and yet, in point of luxuriant fruitfulness, this country may be denominated the Garden of Cornwall.

Decomposed sienite, as may be seen in the vicinity of Menacchan, especially in passing from this village to Tregonwell Mill, is extensively applied as a manure to slate lands in that district, and, as I understood, with evident advantage. In the parish of Mullyan, a decomposing greenstone is very extensively applied as a manure.

The last soil which I have to mention is that superincumbent upon serpentine; this, in comparison with the foregoing ones, is limited in extent, occurring only in the peninsula of the Lizard, and in a circumscribed spot near Liskeard. If we consider the "*Lizard peninsula*" to consist of the lands south of a line drawn from the Helford Harbour to the Loe Bar, it will be found that the serpentine soil

will just occupy one-third of its area. This soil, although inferior in fertility to that of many districts in Cornwall, is by no means so sterile as we should have expected from the abundance of magnesian earth in its composition. In France we have an example of a large chalk district rendered barren by the presence of magnesian earth.* No opportunity has been afforded me of examining in detail the peculiar characters and relations of serpentine soil; I hope that some other member of the Society will prosecute the enquiry. To the botanist this district is well known as the habitat of the *erica vagans*. This elegant heath seems to find a magnesian soil not only congenial, but essential to its existence, for notwithstanding its profusion on Goonhilly Downs, not a single specimen is to be found beyond the line which defines the boundary of the serpentine formation. The botanist will be glad to learn that I have gathered it in the vicinity of Clickertorr, near Liskeard, where the serpentine formation again betrays itself, accompanied with an evident deterioration of soil in its immediate vicinity.

When it is considered how constantly the rocks of Cornwall are intersected by metallic and other veins, carrying every species of mineral matter, it cannot be deemed extraordinary, if we occasionally find some rare salts in

* Trans. Geol. Society of London. vol. ii. p. 175.

its soils. The Rev. William Gregor found in a schistose soil near Creed, and also in the vicinity of Helston, several uncommon substances, amongst which was a *muriate of manganese.* In the vicinity of Redruth I detected a considerable proportion of *sulphate of iron*; the soil which contained it had not been manured, as I was informed, by calcareous sand, or it might probably have been converted into *gypsum.* Veins of iron appear to improve the country through which they pass. I have seen an example of this fact in the parish of St. Mewan.

In the view which has been just taken of the geological structure of Cornwall, in reference to its agricultural œconomy, it would appear that the fertility is much greater than that which usually occurs in a country composed of primitive rocks. This peculiarity, however, is not greater than that which distinguishes its geological character; granitic countries usually present a bold and varied outline, whereas the aspect of Cornwall is tame and uniform. "I went into Cornwall," said a geologist of well known celebrity, "to see an example of a primitive country, but instead of an example, I found an exception."

The same observation would apply to the agricultural character of the county. In general, primitive formations disintegrate into rugged piles, whose acclivities are too steep to allow any accumulation of soil, and conse-

quently they but rarely constitute the fertile parts of the globe. As far as the imperfect state of our knowledge will allow us to generalize, it would appear that PRIMITIVE rocks are accumulated towards the poles, and that the great mass of SECONDARY formations is found to occupy the middle and southern latitudes, which constitute a portion of the globe eminently calculated for the abode of man, and of the animals which are subservient to his wants, or indispensable to his comfort. This observation, however, must be regarded only as a loose and vague conjecture; nor should I have introduced it into this memoir, had it not coincided with the result of the extensive and laborious researches of a celebrated geologist, who has traversed the continents of Europe and America, with the view of examining their geological structure and relations; I need not state that I allude to Mr. Maclure, of Philadelphia, a name well known to our Society from the splendid map of the United States of America, and the suite of specimens illustrative of their geology, which have been lately presented by that gentleman.

By an arrangement of rocks similar to that which I have stated, nature is continually heaping, in the middle and southern latitudes, the matter consolidated by the action of animal and vegetable life, and might, therefore, as Mr. Maclure ingeniously observed, tend to augment the diameter of the globe in those places, and

of course to give the appearance of flatness to the poles.

I shall conclude these notes on the soils of Cornwall, with a few observations upon the different kinds of mineral manure which are applied for their cultivation and improvement.

SEA SAND is very generally used for this purpose, but as this substance is various in its composition, it is obvious that its operation must be very different in different parts of the country; its mechanical action, however, in dividing the particles of the soil, applies equally to every kind; it moreover may be said generally to impart a small quantity of sea salt to the soil.

CALCAREOUS SAND, consisting of comminuted shells, is the species more generally employed; and the quantity which is every season carried away from different parts of the coast for the purpose of manure, almost exceeds belief. From Bude, in the parish of Stratton, it has been ascertained that in one day as many as four thousand horse loads have been taken; and from the harbour of Padstow, it has been computed, that fifty-four thousand cart loads are annually carried. The expense of land carriage for sand, used in the county, has been considered as amounting, at least, to thirty thousand pounds annually.

With respect to the composition of "shelly sand," it will be found to vary with the state of the tide, and the direction of the wind,

circumstances which the farmer ought always to notice; for when the wind is blowing off land, the lighter particles of the sand are thrown upon the beach, and it is more calcareous in its composition. On examining samples of the sand usually employed, I have found it generally to contain from 60 to 64 per cent. of carbonate of lime. That its beneficial operation depends upon the presence of calcareous matter there cannot be any doubt, but at the same time, we are borne out by unequivocal facts in believing, that the sea salt, with which it is impregnated, contributes materially to its fertilizing powers. This opinion I have lately stated before a Committee of the House of Commons, appointed to enquire into the laws respecting the Salt Duties, and I am anxious to record such an opinion in this memoir. Amongst the facts to which I allude, as bearing strong testimony to the truth of this opinion, is the striking circumstance of the farmers sending several miles to the harbour of Padstow for the very sand which is drifted to their lands, and might, therefore, be obtained with little trouble, and no expense.

The calcareous matter of the sand would seem to undergo different changes, and to be disposed of more or less readily, in the different kinds of soils to which it is applied; its conversion into *gypsum*, or sulphate of lime, as I have already mentioned, appears occasionally to take place. In *growan* soils it undergoes the

least change. I examined several of these soils, that had not received a sanding for a considerable length of time, and I found them to contain about five per cent. of carbonate of lime, two-thirds of which were in the form of an impalpable powder, and the remaining one-third in that of fine sand. A series of comparative experiments made with different soils, would furnish interesting and important results. On the supposition that the action of this sand was purely chemical, our worthy President suggested the probability of gaining some advantage by previously grinding it so as to reduce it to an impalpable powder. Mr. Bucestow, an intelligent farmer, accordingly made the experiment, and he states that the result was favourable; no conclusion however can be drawn from one experiment; numerous and repeated trials are necessary to establish the utility of any practice, in an art so obscure as that of applying with success the different species of mineral manure.

How far the presence of gypsum in any of the soils of Cornwall may contribute to their fertility, is a subject well worthy of farther investigation. I have already shewn that it might be easily produced by the admixture of calcareous sand and decomposing pyrites: examples in which the elements of these bodies, when presented to each other under circumstances favourable to chemical action, enter into new combinations, and produce gypsum,

are familiar, and I have already dwelt upon the subject in a former paper. I might now remind the mineralogist of many more instances, amongst which are the well known specimens of oyster shells studded with crystals of selenite from Shotover, evidently produced by the action of sulphate of iron upon their calcareous elements. The same theory will also explain the generation of alum, from *aluminous shale,* at the Hurlet Mine, near Glasgow.

The use of gypsum as a manure has been questioned by several intelligent farmers: various testimonies however in favour of its efficacy, have been presented to the Board of Agriculture by Mr. Smith; it must, nevertheless, be admitted, that in this kingdom it has never been employed with the signal success which marked its adoption in America, and which was so palpable and extraordinary, as to have at once ensured its universal introduction. Whenever any doubt or hesitation betrayed itself with respect to the extent of its fertilizing agency, it was only necessary to sprinkle a small quantity on a meadow, in order to produce entire conviction, and this was usually done in the form of letters, or characters, which in a few days became so much more luxuriant than the surrounding grass, as to be visible at a considerable distance: it is, I understand from Mr. Maclure, chiefly applied to grass lands as a *top dressing,* in the propor-

tion of one bushel, weighing 70 lbs. to an acre, and the Americans explain its operation by supposing it to depend upon its solubility in water, and its consequent absorption by the roots of the grass; they have accordingly found that by burning it, and thereby diminishing its solubility in water, fifty or sixty bushels are not so efficient as one, before it undergoes that operation.

When this substance was first introduced into America, which was about twenty-five years ago, it was imported from the quarries of Montmartre, and in such request was it, that a bushel of wheat was usually given for the same measure of gypsum; it is now obtained from Nova Scotia, not having been hitherto found within the States; and it may perhaps serve to convey some idea of the extent to which it is applied, when I state that Mr. Maclure assured me that not less than three hundred vessels are constantly employed in the traffic, and that in Philadelphia twenty merchants at least are solely engaged in supplying the demand for it. Its efficacy appears to be considerably encreased by applying it in a minute state of division, and a want of attention to this circumstance may possibly have rendered its advantages less conspicuous in England. In America three or four hundred mills, of a peculiar construction, have been erected in different parts, with which it is ground to an impalpable powder. It appears,

however, never to answer so well within fifteen or twenty miles of the sea, nor in wet lands; this, perhaps, may have been another source of disappointment. We may infer, therefore, that the value of the application may vary with the character of the soil, especially as it regards its power of absorbing and retaining moisture; many valuable hints upon this point are to be found in Sir H. Davy's masterly system of agricultural chemistry.

It is undoubtedly necessary, before we can hope to apply any mineral manure with advantage, to understand the nature of its operation; I trust, therefore, that I may be excused for hazarding the following theory in explanation of the *modus operandi* of sulphate of lime. The solubility of this substance in water affords a great facility to its introduction into the circulating fluids of a plant, and hence whatever diminishes this property diminishes also its fertilizing powers; it is thus, therefore, enabled to penetrate and pervade the whole vegetable organization, and to enter into combination with its woody fibre, by which the density of its texture will be encreased, and consequently the vascularity of the plant, and the evaporation from its leaves, in the same ratio, diminished: from these views it would appear that gypsum does not act by effecting any chemical change in the soil, but solely by diminishing the plant's evaporation; this idea seems to be fully borne out by the evidence

which is furnished by the different circumstances attending the operation of this manure: we find, for example, that succulent vegetables, planted on dry soils, are those which are principally benefited by its application, and that the various grasses so manured, retain their verdure in the driest season, and on the most arid lands; and at the same time we find that these crops, especially clover, acquire a proportionate encrease in the density of their fibres, that is to say, they become much more rank and stubborn, and often to such a degree, that in America, where its effects are best known, sheep frequently refuse feeding upon the stalks: by analysis, gypsum would most probably be discovered in their composition, but I have had no opportunity of submitting them to experiment. Upon the same principle we find that under circumstances, or in situations, where the evaporation from a plant is provided for by a constant supply of moisture, that such a check to it becomes unnecessary, and therefore that the effects of gypsum cease to be apparent.

It remains for me to conclude these notes upon the soils of Cornwall with an apology for their numberless imperfections, and for the abrupt and unsatisfactory way in which I have dismissed many of the more important points of the enquiry. The truth is, that with this memoir I abandon the study of geology. The pursuit of the science commenced with my

residence in this interesting county, and it must terminate with it. I part with it, however, with the reluctance of an old friend, who has furnished me with much delight and amusement, during the exercise of a laborious and anxious profession. That I may not be seduced from my present resolution, although I have not, like Bishop Watson, in imitation of the idolaters of old, *burned my books,* yet I have taken a no less effectual step to wean myself from the pursuit—I have given away my mineralogical specimens.

XVII.—*On a Process of refining Tin.*

By JOHN HAWKINS, Esq. F.R.S. &c.

MEMBER OF THE SOCIETY.

It is well known that the grain tin of Cornwall sells for a much higher price than the block tin, which is produced in the same county; and that this difference in their value arises from the greater purity of the former, which renders it more fit for a variety of purposes.

The causes of this difference in the purity of the two sorts, are generally supposed to be of such a nature as not to be removed or modified; stream tin alone, as it is said, being fit for the production of grain tin, and the quantity of grain tin being necessarily limited by the supply of that fuel which is peculiarly adapted to it.

This, I believe, is the popular opinion, and with all the respect which is due to it, I am nevertheless disposed to think that it is fallacious.

For although it be true that the produce of a blowing-house must necessarily depend on the supply of that sort of fuel which is fit for it; yet it is by no means clear that coak may not be substituted for charcoal, and that block tin may not be converted by a process of refining into grain tin

I was led to form this conclusion by a short view which I took of the operations in a blowing-house in the autumn of 1791.

It appeared to me that as tin was specifically lighter than most metals, and more fusible than most, some advantage might be taken of these two combined circumstances to refine even the impurest mixture of tin by precipitation

As I had no opportunity of submitting my ideas to the test of experiment, the observations which I drew up and communicated to my friend, Mr. William Gregor, would have remained in that oblivion which results from a pursuit long since abandoned, had I not been informed that the attention of this Society was by no means exclusively directed to an object (the mineral history of Cornwall) which, under the direction of its zealous and enlightened secretary, it was so well calculated to promote; but that no hint which might be offered for the improvement of the mining and metallurgical

operations of this county, would pass unregarded.

The question, indeed, whether block tin may be refined in the way that I have suggested, is so intimately connected with the interest of Cornwall, that I need no apology for submitting to the Society the result of my imperfect endeavour to answer it.

It is fair, however, in this place to state, that I found I had been anticipated in the ideas which suggested this improvement, by two very able French chemists, Messrs. Bayen and Charlard, who, in the course of their enquiries into the causes of those poisonous effects which were ascribed in France to the use of pewter, made the following observations on the quality of our Cornish tin.

Messrs. Bayen and Charlard found the West Cornish grain tin, the Banca tin, and the Malacca tin, to be equally malleable; and that they could be bent a long while in different directions without breaking. They possessed this flexibility and softness to such a degree, that tin alloyed with the minutest portions of arsenic could not be put into any sort of competition with them. Bayen affirms that these three sorts of tin are pure, i. e. free from all natural and artificial admixture, and as perfectly equal in this respect, as gold of 24 carats, or silver of 8 ounces, from the European or South American mines.

On the other hand, Geoffroy observes of the

block tin, that it varies in fineness in different parts of the same block; "the upper part, he says, is very malleable, and so pliable as not to be fit for working before it has had a mixture of copper in the proportion of 3, and sometimes of 5 lb. in the cwt. The middle part of the block is harder, and requires only 2 lb. in the cwt. and the bottom part is so brittle as to require lead before it can be worked."

This perhaps gave occasion to the common opinion in France, that the exportation of pure English tin was prohibited, and that a certain portion of alloy was prescribed by law.

The observation of Geoffroy induced Mr. Bayen to express a wish to procure more information concerning the smelting of tin in Cornwall. "For instance," says he, "whether the English have any other means of producing pure tin than *the separation of the upper part of these blocks,* and whether merely for the reason cited by Geoffroy, they add a portion of copper and lead. Does not the precipitation of a heavier substance to the bottom of the mass, and this spontaneous purification of it, require a more circumstantial explanation? And may we not suppose that some time is required to effect this separation, and even the art of preserving the moulds hot to a certain degree, in order to prolong the fluid state of the metal; by which means the extraneous and more heavy substances are completely separated from the upper part of the block, less completely from

the middle part, precipitated to the bottom, and there fixed by refrigeration."

Mr. Bayen suspects this to be the most secret part of the process of tin-smelting in Cornwall, and confirms the idea of the spontaneous precipitation by some experiments of his own.

After holding several masses of tin 24 hours in fusion, he invariably observed that all those which contained copper, bismuth, and lead, contained tin of two kinds at least. The upper part held little of this mixture, the lower much. He was assured by the pewterer, in answer to his enquiries, that sometimes after smelting a considerable quantity of tin at once, they found at the bottom of the mass some pounds of the metal so brittle as not to be fit for use. To prevent which separation from taking place, they were accustomed to stir it gently round from time to time, during the fusion, with the iron ladle with which they afterwards pour it into the moulds.

With the same view to preserve an equal mixture in the mass, I have observed that the Saxon blowers do not permit it to subside in a mould like other metals, but after a careful stirring of the fluid tin in the float, pour it over a broad sheet of iron, where it instantly coagulates in the form of a thin plate.

The above-mentioned observations shew how quickly the precipitation of the heterogenous metals takes place, and how early it must have occurred to the rudest empiric that some use

might be made of it. Accordingly, this principle seems to have long been the basis in some measure of the process of refining grain tin in Cornwall, although unfortunately, from a total want of science, and a blind adherence to traditionary practice, the Cornish blower has not availed himself of it, to the extent to which he might have carried it, as will appear from the following account of his process.

The Cornish refiner *teams* the metal from the float into a cauldron of cast iron, and maintains its fluidity by a small fire beneath, during the space of four hours. During this time, green branches previously attached to the bottom of the kettle by a mechanical contrivance, produce a great ebullition in the fluid mass.

At the end of three hours, the wood being removed, the ebullition ceases, and the mass is suffered to rest one hour, in which time the heavier parts of the fluid subside. The upper part (about $\frac{1}{2}$) is then carefully laded off and poured into moulds.

It is difficult to conceive what good effects in the purification of the mass, so long a heat and this ebullition can produce. It appears then, that the principles upon which the process ought to be founded, are very imperfectly, if they are at all understood by the Cornish refiner. The true process, as I have already observed, is a precipitation which spontaneously takes place in every mass of fluid tin

which contains an admixture of other metals, in consequence either of their greater specific gravity, or of the greater degree of heat which is necessary to keep them in a state of fluidity: those metals which cannot be separated from tin by the difference in their specific gravity alone, (as is the case I believe with zinc) being readily precipitated by refrigeration.

It is well known, in fact, that tin longer retains its fluidity than almost any other metal, and that most metals are heavier in a fixed than in a fluid state. This last is the case, according to Reaumur, with silver, copper, lead, and tin; for if you cast into a mass of either in fusion a piece of the hard metal, it will immediately sink to the bottom. But it is not the case, I believe, either with iron or with antimony: for whatever may be the law of dilatation by heat in fluid metals, their greater or less solidity, when fixed, must depend in some measure upon a certain crystalline arrangement which the particles assume at the moment of coagulation. Now antimony rarely, if ever, occurs in the mixture which is exposed to fusion; and the specific gravity of iron compared with that of tin, is, according to Sir Humphry Davy, (vide his Chemistry) as 7.70 to 7.29; and the difference must be greater when both arise in a fluid state, as iron expands while tin contracts by setting. It follows therefore from all these considerations,

that a partial application of heat to the superior parts of the fluid mass, if it could be effected, and a partial removal of it from the lower and impurer, must greatly promote this precipitation of the heterogeneous metals*.

I proceed now to consider in what manner, a process which is founded on these principles, may best be carried into effect.

1st.—In order that a more complete division of the different qualities of the mass may take place, I propose that the refining vessel should be of a higher and a more narrow form than that which is at present in use: for if we suppose the sides of this vessel to be exposed to an equal heat, the degrees of this separation will extend in proportion to the protraction of the cylinder.

2dly.—The fire should be applied not to the bottom of the vessel as at present, but to its whole circumference.

It appears to me that this is a necessary consequence of the alteration in the form of the vessel; otherwise, the metal, although fluid at bottom, might have a tendency to coagulate at top, where, in order to facilitate the precipitation of the heavier and heterogeneous parts, a greater degree of fluidity ought to prevail.

3dly.—It would greatly conduce to the success of the preceding operation, if the diameter of the vessel were made gradually to diminish

* This is precisely the reverse of the process of eliquation.

from the bottom to the orifice, by which means the upper part would be exposed to the nearer action of the fire. The duration of the fluidity depends on the degree of purity of the mass, and may be regulated by experiments.

4thly.—In order to enable the refiner to draw off the purer parts of the mass without disturbance, I would recommend that tap-holes should be applied at different elevations, to the sides of the cylinder.

5thly.—Previous to the tapping, the external heat should be diminished, and a gradual refrigeration take place from the bottom to the surface of the mass, the different qualities of which may be tapped off in succession.

Having had no opportunity of submitting to the test of experience the process which I here recommend to the notice of practical men, I am well aware of the possibility that the result may prove somewhat different from what is here contemplated.

Some causes of obstruction may arise from the attractions of metals to each other in a fluid state, not being perfectly understood. Some metallic mixtures too possess a less degree of density than might be inferred, by calculation, from the density of the several ingredients. It is true, likewise, that tin most readily unites with iron, and dissolves it in a heat far less than that in which iron by itself melts: it will consequently retain the iron longer in fusion. I suspect too that the

contraction which is usually the consequence of a metal passing from a fluid into a fixed state, must depend in some measure upon the period of refrigeration. The following useful remarks on this process are contained in a letter from Mr. Wm. Gregor, of the date of 1793. "I should think that experiments on the alloy of iron and tin would be useful, in order to discover the maximum of iron which a given quantity of tin would take up. I should also like to know, whether, in a long perpendicular cylinder of tin which is alloyed with iron and kept in different heats, the specific gravity increases in any determinate ratio, according to the distance from the surface, and at what distance is the maximum. As the iron over and above the quantity which tin can take up in a heat that will keep it in a melted state, is only kept from precipitation by the friction which its particles meet with in their descent, would any mechanical motion, such as a smart concussion, communicated to the melted mass, contribute in any way to the further descent of the particles of iron?"

On consulting the very elaborate work on iron by Rinman, I found that the dissolution of one part of raw iron requires 22 parts of tin, and that this mixture is somewhat harder than tin. He says too, that sulphur much facilitates this combination, i. e., it enables portions of each metal more nearly equal, to unite; and that the same effect is produced by arsenic in a re-

guline state, when added to the mixture of the two metals.

According to Rinman, the change which is most observable in tin which is alloyed with the least portion of iron, is, that it does not crackle when bent. An easy trial too of its purity may be made by its flexibility; for small round bars of tin, a line in thickness and six inches long, may be bent 80 times backwards and forwards in an angle of 90 degrees, without breaking.

XVIII.—*On the Introduction of the Steam Engine to the Peruvian Mines.*

By HENRY BOASE, Esq.

TREASURER TO THE SOCIETY.

(Read at the Anniversary Meeting, Sept. 1817.)

As the introduction of Cornish machinery and Cornish intellect to the Spanish American mines, hitherto interdicted to foreigners, will probably form a remarkable epoch in the history of mineralogy, some notices of that singular event, may perhaps be deemed worthy of record in the annals of the Cornwall Geological Society.

Occurrences trivial in themselves, and apparently fortuitous, sometimes lead to important results. Among the captains, or foremen, of our Cornish mines, there are not a few, who, in addition to great skill in practical mining, attain to much mechanical knowledge and in-

genuity. Captain Richard Trevithick, of Camborne, is one of that superior class of miners, and one whose talents and attention had been long employed in plans to increase the power of the steam engine. He so far succeeded as at length to obtain a patent for his invention. In the mean time he had constructed a working model of his high pressure engine, which was so perfectly finished, that it found its way to London as a cabinet curiosity.

About the same period, a native of Switzerland, M. François Uvillé, had found in Peru some of the richest mines falling into decay, or totally drowned from the impossibility of draining them by manual labour; and hearing also that these mines were richer in silver ore than those of Mexico, he conceived the idea of introducing the steam engine, and determined to make the requisite enquiries when he returned to Europe. It appears that he came to London in the year 1811, but met with no encouragement to pursue his plan, on account of the impossibility, as it was thought, of transporting such ponderous materials several hundred miles over mountains inaccessible to any species of wheel carriage; and also from the inefficacy of steam in an atmosphere so rare as that on the elevation of the Peruvian Cordilleras. About to leave England in despair of accomplishing his great object, and passing by Fitzroy-square, he accidentally saw the model of a steam engine exposed for sale in the shop

of a Mr. Roland. He examined it, and being struck with the simplicity and excellence of the principle and construction, he purchased it at the price of twenty guineas. This was the Trevithick model. Mr. Uvillé took it to Lima, and hastened to try its effects on the highest ridges of Pasco. The experiment so convinced him and others of the adequacy of its powers and the practicability of conveying the machinery in parts, that on the 17th July, 1812, he formed an association with Don Pedro Abadia and Don José Aresmendi, opulent merchants of Lima, for the purpose of contracting with the proprietors of the flooded mines. The marquis de Concordia, then Viceroy of Peru, approved the plan, and, under his protection, the new company entered into contracts to draw several of the principal mines, for certain shares of the gross produce of ores, making an average ratio of 25 per cent. or one fourth of the whole. These contracts were made in the month of August, 1812, and in pursuance thereof Mr. Uvillé again embarked for Europe, and reaching Jamaica, he took his passage to Falmouth in the Fox Packet, Capt. Tilley, which arrived in the early part of the summer, 1813. Mr. Uvillé's mind was too full of the flattering expectations which his scheme inspired, not to be making frequent enquiries among his fellow passengers about mines and engines. One day conversing on this favorite subject with a Mr. Teague, and

expressing an anxious wish to find out, if possible, the author of the model he carried to Lima, he was most agreeably surprised to hear Mr. Teague reply: "Mr. Trevithick is my near relative, and within a few hours after our arrival at Falmouth, I can bring you together." It so happened accordingly, and in consequence Mr. Uvillé resided several months with Capt. Trevithick at Camborne, and was by him instructed in the practice of mining, and in the management of machinery.

After acquiring much practical information in Cornwall, Mr. Uvillé, accompanied by Mr. Trevithick, visited other mining districts, and London. He was introduced by a scientific gentleman, Mr. Campbell, of the East India House, to Messrs. Bolton and Watt, as being the first steam engineers in the universe. He explained to those gentlemen the elevation of the mines, and the mountainous precipices to be surmounted, and they were of opinion that it was not possible to attain the object in contemplation.

Notwithstanding the weight of a decision from such high authority, Capt. Trevithick was not deterred from the pursuit. He applied his mind intensely to some improvement of his high pressure engine, and, having succeeded, he entered into an engagement with Mr. Uvillé, on the 8th of January, 1814, to provide the apparatus for nine engines, which cost about £10,000. and were dispatched by the ship Wild-

man, which sailed from Portsmouth on the 1st September, 1814, accompanied by Mr. Uvillé and three Cornishmen, namely, Thomas Trevarthen of Crowan, Henry Vivian of Camborne, and William Bull of Chasewater, to direct the erection of the machinery, permission having been granted by the British government. They arrived safely at Lima, and were welcomed by a royal salute, and public rejoicings. Such however are the almost insurmountable difficulties to the transport of such heavy materials, that it was not till the middle of the year 1816 that the first steam engine, ever seen in South America, began to work.

Great ceremony, it appears, was observed on the occasion, and the most distinguished honors vouchsafed by the viceregal government. The official deputation appointed to superintend this new and very extraordinary operation, made a report to his excellency the Viceroy, conceived in the high sounding style of Spanish diplomacy. This report was published by authority in the Lima Gazette of the 10th August, 1816. "Immense and incessant labour," (they say) "and boundless expense, have conquered difficulties hitherto esteemed altogether insuperable; and we have, with unlimited admiration, witnessed the erection, and astonishing operation of the first steam engine. It is established in the celebrated and royal mineral territory called the mountain of Yauricocha, in the province of Tarma; and

we have had the felicity of seeing the drain of the first shaft in the Santa Rosa Mine, in the noble district of Pasco." "We are ambitious" (they continue) "of transmitting to posterity the details of an undertaking of such prodigious magnitude, from which we anticipate a torrent of silver, that shall fill surrounding nations with astonishment." They then go on to name a number of individuals on whom "the eternal gratitude of all good Spaniards," is invoked; and it is somewhat remarkable that the only Englishman mentioned by name in this list of worthies, is *Mr. Bull!*

In the mean time Mr. Trevithick had been employed in providing further supplies of engines, considerable quantities of coining apparatus for the royal Mint of Peru, and also furnaces for purifying silver ore by fusion; an experiment, which will be, if it succeeds, of incalculable advantage to the American mines, as amalgamation becomes more and more expensive and limited, by the want of quicksilver. This second cargo of machinery was sent by the ship Asp, a South-Sea Whaler, which sailed from Mount's Bay on the 20th of October last, and, after a quick voyage, arrived at Lima on the 6th of February. Mr. Trevithick went out in this vessel, accompanied by Mr. Page, of London, Attorney-at-Law, and James Sanders, an Engine-maker, of Camborne. He was immediately presented to the Viceroy; was most

graciously received; welcomed by the most flattering attention of the inhabitants; and his arrival was officially announced in the Lima gazette of the 12th February. By this gazette, public notice was given of the completion of the second engine, said to be far superior in size and beauty to the first, with a detail of the wonderful effects produced; and announcing the reception of some parcels of ore of extraordinary richness, raised from the mines thus restored by the operation of the steam engines; and continues thus—" To this agreeable intelligence we have the happiness to add that of the arrival of the British ship Asp, from London, having on board a large quantity of machinery consigned to the royal Mint of this City, and for constructing eight engines equal to those already erected on the Santa Rosa and Yauriacocha Mines in Pasco, with this advantage, that they are of the latest improvement. But that which is of still greater importance, is the arrival of Don Ricardo Trevithick, an eminent professor of mechanics, machinery and mineralogy, inventor and constructor of the engines of the last patent, and who directed, in England, the execution of the machinery now at work in Pasco. This professor, with the assistance of the workmen who accompany him, can construct as many engines as shall be wanted in Peru, without the necessity of sending to Europe for any part of these vast machines. The excellent character of

Don Ricardo, and his ardent desires to promote the interests of Peru, recommend him to the highest degree of public estimation, and make us hope that his arrival in this kingdom will form the epoch of its prosperity, through the enjoyment of its internal riches, which could not be realised without such assistance, or if the British government had not permitted the exportation from England; an object hitherto deemed unattainable by all who know how jealous that nation is of all her superior inventions in the arts or industry."

It is to be observed, that the engine which has obtained such singular celebrity in South America, is on the principle of Capt. Trevithick's improvement, whereby he sought, through intense heat, to impart a greater elastic force to the steam, and which is necessary to its application in the rare atmosphere of very elevated regions: a result however not at all in contemplation when he was studying the improvement.

So much importance was attached to Mr. Trevithick's personal superintendance, that the Viceroy ordered the Lord Warden of the mines to escort him with a guard of honor to the mining district, where the news of his arrival in America caused the greatest rejoicings; and many of the chief men came to Lima, a distance of many days journey over the mountains, to welcome him. Mr. Uvillé wrote to his associates, "that heaven had sent him

out for the prosperity of the mines; and that the Lord Warden proposed to erect his statue in massy silver." In this narrative of incidents, almost romantic, it is not the least to be remarked, that a Cornish miner should be found superintending the Royal Mint of Peru. Such, it appears, is the fact; and that Mr. Trevithick had also been directed to use his endeavours to increase the powers of the coining machinery six fold: a circumstance which shews the confidence of the government in obtaining a vast increase of the precious metals. It was necessary to augment the power of a water wheel: but the means of so doing were to be found only within the enclosure of a convent of one of the strictest orders, into which it was not permitted for any male, (except the father confessor) on any pretence, to enter. The officers of the Mint, having before made every effort to obtain access, were so convinced of the utter impossibility of succeeding, that they could not be induced to renew the application. That which the strong arm of power had failed to do, Mr. Trevithick accomplished; and the triple doors were unbarred to a layman, a foreigner, and a heretic. Probably he had not yet learnt the fearful respect with which these consecrated retreats are regarded by the natives; and unaccustomed to shrink from difficulties, he resolved to go straight forward, and boldly ask admission. Whether the novelty of such a visit, or a curiosity to

see the celebrated stranger, removed the interdict, does not appear: entrance however was obtained; and the manner and result cannot be so well told as in his own words. "Without the knowledge of Don Abadia, or any one except Mr. Page and my interpreter, I walked up, without seeming to know there was any objection to admit men, and rung the bell at the outer door. A female slave came to the grate, to whom the interpreter told my name and business, which she carried in. Presently three aged nuns appeared, and said I could not be admitted. I informed them that I had come from England for the purpose of improving the Royal Mint, and could not proceed without examining and measuring the water-courses. They then retired, and, after consultation, we were admitted, conducted over the premises, and shewn the chapel and other places without reserve."

The latest accounts left Capt. Trevithick in the enjoyment of increasing distinction, and a flattering prospect of great wealth: having, in addition to his emoluments as patentee and engineer, one-fifth part or share in the Lima Company, from which, it is said, on a moderate computation, £100,000. per annum may be expected. His great influence in the country, his zeal for the prosperity of this Society, and the promises, repeated since his arrival in Peru, joined to his knowledge of mineralogy, will enrich our cabinets with a more splendid

and instructive series of South American specimens than has yet reached Europe.

These notices of the extraordinary fact, of Cornwall stretching out the beneficent hand of science, to the remotest regions of the earth, will excite, perhaps, different feelings and anticipations in the mind of the statesman, the miner, and the merchant; but the philosopher will rejoice in the diffusion of useful knowlege. He will hail with pleasure every approach to that free international communication of the benefits peculiar to each, which the best of men have wished, and the wisest recommended. In this instance we see the barriers of national jealousy and religious bigotry yielding to the force of truth. We have seen the unprecedented phenomenon of a Lima gazette extolling the superior attainments of foreigners, and the liberality of the British government, for imparting the benefits of our improvements.

Whether "the torrent of silver," which the Peruvian viceregal deputation so confidently anticipate, will produce effects analogous to those experienced in Europe by the great influx of the precious metals in the 16th century, and accelerate the march of improvement in art and science, may form a subject of curious speculation. To a scientific society, it must always be pleasing to contemplate the progress of instruction: but at the same time it will be the cause of regret to the Members

of this Institution, that it may still be said, 'Cornwall has no school of mines—no professor's chair—no suitable encouragement to promote the pursuit of mineralogical science.' Shall we wait to be taught the value of such establishments by the half-peopled, half-civilized wilds of America?—I hope not.

XIX.—*Miscellaneous Notices of Facts, connected with the Mineralogical, Geological, and Œconomical History of the County of Cornwall.*

(Extracted from the Minute Book of the Society.)

I.—Kupfer-Nickel.

KUPFER-NICKEL has lately been raised from a mine called *Pengelly,* in the parish of Saint Ewe, at about twenty-five fathoms below the surface; the lode runs east and west, and is about seven inches in thickness. This mineral may have been discovered before in some of our copper mines, but if I may trust to the result of my enquiries on the subject, it is of very rare occurrence; the cabinet at Menabilly never contained a single specimen; this point is dwelt upon because Professor Jameson places Cornwall the *first* upon the list of the *habitats* of *kupfer-nickel*; whence

we might conclude that it was met with very frequently.

There is one curious circumstance appertaining to the ore, viz. that it assumes a different colour and external appearance; it is not the *bronze-red* ore only which contains nickel, but that portion of it also which has the semblance of arsenical pyrites; a fragment of it well roasted leaves a green oxide, whence we are led to infer that the arsenic and nickel which form the alloy, if alloy it be, in this ore, vary in their relative proportions.

WILLIAM GREGOR.

II.—CAVERN IN DOLCOATH MINE.

In November of 1814, a large cavern was discovered in the principal vein in Dolcoath copper mine, at the depth of one hundred and seventy fathoms from the surface; it is remarkable on account of its dimensions, being the largest ever found in the county: its form was very irregular, from eighteen to twenty fathoms in length, three fathoms high, and from four to nine feet wide; in the lower part, and wedged between the walls, there are several rocks, between which are spaces which communicate with other cavities below. The air is contaminated with large quantities of fixed air, and extinguishes flame. The country in which this cavern occurs is slate.

JOHN RULE.

III.—Stalactites.

At the forty fathom level, in the mine called "*Little Bounds,*" at Cape Cornwall, a drift has been carried a considerable distance under the sea; the agent, Mr. Chenalls, observed in this spot that there was a continual formation of *stalactites*. Dr. John Davy and Mr. Majendie, in consequence of this report, visited the spot; it had been closed for two years previously, and before it was shut up Mr. Chenalls had carefully removed all the *stalactites* which then existed. Upon examination, it was observed that a considerable formation of fresh *stalactites* had taken place during the interval just stated; some were eighteen inches in length, and about one inch in diameter. The *stalagmites* directly underneath them are of much larger dimensions; both have the same yellowish brown colour, and consist of *oxide of iron*. Dr. Paris has suggested that they are the result of decomposed pyrites, which form in the first place a *sulphate of iron,* that gradually loses its solubility by peroxidation, and is deposited in the form and manner which is here discovered.

A. Majendie.

IV.—Gregorite (*Menacchanite*) discovered at Lanarth.

Some sand was lately sent to me by Colonel Sandys, from his estate at Lanarth, in the

parish of St. Keverne: he stated that it was taken from a stream of water which ran near his house, and that any quantity of the sand in question might be obtained, if required. Its external characters were sufficient to convince me of its nature. I nevertheless submitted it to experiment, and immediately proved that it was the ore of titanium, in which Mr. William Gregor first detected the existence of that metal, and to which the name of *menacchanite* has been given. Collectors will be glad to hear of this discovery, for specimens of the mineral were becoming scarce, from the exhaustion of the original stream at Tregonwell Mill, which has hitherto, I believe, been its only Cornish *habitat*.

JOHN AYRTON PARIS.

V.—FORMATION OF A SUBSTANCE, RESEMBLING GNEISS, TAKEN FROM A STEAM BOILER at HUEL ALFRED.

The specimen which I am about to describe was given me by Captain John Davy, a zealous and intelligent associate of the Society; it was broken from the interior of the large boiler of the steam engine, erected on Huel Alfred. From its structure and appearance it is impossible to infer its artificial origin, and several of my

geological friends have been puzzled to know to what class of rocks it should be referred. It resembles gneiss more nearly than any other, and in one specimen, metallic veins may be actually seen penetrating its substance.

The formation of this substance is to be explained in the following manner. The water which fed the boiler was derived from the deepest part of the mine, and contained many mineral substances, both in solution and mechanical suspension; by gradual evaporation the former bodies were deposited, as a crust in the interior of a kettle, entangling with them fragments of *mica,* and of other substances which were floating in the water of the boiler. In this manner the formation of the earthy crust may be easily comprehended—but how can the appearance of metallic veins be explained? with equal ease and truth. After the deposition of the stony matter, the working of the engine was suspended for several months, during which interval the crust dried, and of course cracked; upon its being again set to work, the water was derived from a different part of the mine, and contained pyritical and other metallic impurities, which were deposited in the fissures, and upon the surface of the former crust. I have another specimen which was presented by Captain Hodge, a duplicate of which is in the cabinet of the Society; in this the fissures are filled with crystals of *sul-*

phate of lime. I have already noticed it in my paper upon a "*Recent Formation of Sandstone.*"

JOHN AYRTON PARIS.

VI.—A NEW SUBSTANCE, FOUND ACCOMPANYING "WELSH CULM."

The species of coal known by the name of culm, "*Glanz Kohle,*" is imported on account of its purity, for the purpose of smelting tin. Mr. William Gregor informed me, shortly before his death, that he had observed amongst the heaps of this coal, lumps of a much more dense texture, and which were perfectly uninflammable. In order to decompose it, he powdered it, and added twice its weight of *nitrate of barytes,* and subjected it to heat in a platina crucible; when, to his great astonishment, a violent detonation took place, accompanied with a copious evolution of *prussic acid* vapours, and upon examination he found the residue in the crucible to consist of the *prussiate,* and *carbonate of barytes.* Since Mr. Gregor's death, I have examined his chemical memoranda, and am thereby enabled to extract the following facts. From different experiments, the specific gravity of this substance appears to be 1,627. Fifty grains of *the coal* were mixed with 200 of *nitrate of barytes,*

reduced to powder, and placed in a platina crucible, which was set in a common fire; before the crucible became red hot, a violent detonation took place, with the disengagement of a brilliant light and vivid heat, which rendered the crucible and its cover red hot; a porous light greyish mass, mixed with black streaks, remained, which smelt of prussic acid; this was separated from the crucible and pulverized, when it was introduced into a matrass. Muriatic acid operated upon the powder, and a considerable quantity of an elastic fluid was disengaged; the solution assumed a dark blue colour, and a very light powder was suspended in it, resembling *Prussian blue.* It was poured off with the fluid, and the remainder was a portion of the undecomposed mineral, which, when dried, weighed $23\frac{3}{4}$ grains. This residuum was mixed with 100 grains of *nitrate of barytes,* and treated as before, when a detonation again took place, but with less energy, a greyish mass remaining, which was treated with muriatic acid as before; there was now no blue powder separated, but the lixiviated mass became opaline, the undissolved residuum now weighed $15\frac{7}{8}$ grains; this was again mixed with 50 grains of the *nitrate of barytes,* a brisk detonation and vivid flame were produced; in this case the vessel was exposed to a stronger heat than before, and on the addition of muriatic acid, a blue powder was again separated, when the undecomposed residue was edul-

corated and dried; it weighed $8\frac{1}{4}$, which was mixed with 40 of the nitrate, with the same phenomena, and the same separation of a blue coloured powder by the effusion of muriatic acid; the residue now weighed only $2\frac{1}{2}$ grains; this underwent a similar treatment, and after this, as not one grain remained undecomposed, it ceased to be an object of experiment. A strong smell of prussic acid accompanied the detonations.

I can find no farther account of this curious discovery; indeed increasing ill health put an end to all the chemical enquiries of Mr. Gregor. Imperfect as this notice is, I thought it proper to present it to the Society, as it might induce some of our members to undertake a farther examination, and perhaps to discover an œconomical application of the substance to the formation of *Prussian blue*; at all events, I feel confident that any extract, however crude, from the manuscripts of Mr. Gregor, will be respectfully received by every mineralogist in Europe.

JOHN AYRTON PARIS.

VII.—ON STONES AND CLAYS ANNUALLY EXPORTED FROM CORNWALL, FOR THE PURPOSES OF ARCHITECTURE, MANUFACTURES, AND THE ARTS.

It may be interesting and useful to place upon record the nature and quantity of the

different mineral substances, not metallic, which are annually exported from this county. I have learnt the following particulars upon this subject, and scanty as they may appear, I am willing to present them to the Society, as an example to stimulate others to exertion, who have better opportunities for enquiry, and more numerous sources of information. The total quantity of granite shipped at Falmouth during the last seven years, amounts to FORTY THOUSAND Tons; it has been employed for building the docks at Chatham, and the Waterloo Bridge in London. The lands in the vicinity of Penrhyn have furnished it; indeed the quantity actually quarried has been considerably greater, for many of the blocks, in consequence of being damaged, have been condemned, and sold at a low price to the inhabitants for building and other purposes. The number of men generally employed in quarrying it, is about four hundred: their wages from twelve to eighteen shillings per week, varying with the quantity raised.—The lord of the soil receives one halfpenny a foot for all that is quarried; the freight during war was as high as 25s. per ton, at present it is only 16s. Fourteen cubic feet weigh one ton. The weight of the blocks generally varies from five cwt. to seven tons. With respect to the quantity of granite quarried in every part of the county for the purposes of building houses, constructing bridges, columns, gate

posts, and a variety of domestic purposes, it is impossible to form any estimate.

The amount of decomposing granite (*petunze*) shipped at Charles Town to Worcestershire for the China manufactories, from the 25th of March, 1816, to the same day in the following year, was 2135 tons. That of clay derived from its felspar (*kaolin*) 1775 tons. It is not the least curious circumstance in the history of these clay works, that whilst Lord Grenville is receiving, as proprietor of the land, £700 per annum, Lord Falmouth, for an equal portion of land, does not receive more than £20. This is to be explained by the value of the clay being very different at the periods when the leases were granted. The works contribute more than £150 per annum to the poor. The sum is of course variable.

The *steatite*, or soap rock, near Cape Lizard, is worked by Mr. Dillwyn of Swansea, for which he pays Lord Falmouth, the proprietor, the sum of £75 per annum; about twelve tons are annually quarried and exported. There are also many other valuable clays derived from the decomposition of rocks; and as one of the principal labours of this Society is to form a statistical analysis of the mineral resources of the county, it is to be hoped that some farther account of them will be received.

Near Lelant, 330 tons of clay, derived from decomposed *schistus*, are annually exported to Swansea, for the smelting furnaces.

For the purposes of architecture, there are likewise many rocks which might be profitably and advantageously employed. I shall beg to offer a few remarks upon the durable and ornamental properties of our porphyry: it would furnish a suitable material for the construction of a national column. The patriotic county of Cornwall has furnished granite for the proud memorial of our glory at Waterloo; let her present her *adamantine* porphyry for a triumphal pillar to immortalize our naval superiority.

Sir Christopher Hawkins has furnished me with different specimens of porphyry; that from a quarry at Pentuan, near St. Austle, is fine grained and durable. Norden mentions this quarry of "*fair stone*" which was worked in his time; about three hundred years since. Many of the ancient buildings and churches in Cornwall are built of this or a similar stone. As a testimony of the durable nature of this rock, it may be stated, that the arches and cornices in Restormel Castle, which are composed of it, although built in an early period of the British history, are in a high state of preservation; as are the cornices and mouldings at Place House, in Fowey, built in the reign of Henry VI. which are of the same material.

JOHN AYRTON PARIS.

VIII.—Observations on Gold found in the Tin Stream Works of Cornwall.

Communicated in a letter to John Ayrton Paris, M.D. &c. by Sir Christopher Hawkins, Bart.

I have taken the liberty to send you a few specimens of gold, which I will beg the favour of you to present to the Royal Geological Society.

The gold was found in streaming for tin in a moor near the church of the parish of Ladock.

The specimen of gold intermixed with quartz appears to have formed a part of, and to have been broken off from a lode; pieces of quartz intermixed with gold have not been frequently found. The grains of gold contained in the quills were found in the same work. It is now more than twenty years since John Kellow and Partners requested my leave to stream this moor for tin, and at the same time expressed their inability, unless assisted, to undertake the expense; I therefore engaged a quarter part of the stream work, and have continued it ever since; and I think I may say that, except by the usual dues for land-leave, I have neither gained or lost by this adventure, in which both gold and tin have been found! Our search indeed extended no farther than

by turning over the ancient beds of the river for the gold and tin therein contained, and the gold, when brought to me, I purchased at an adequate price. Other persons more enterprising, might have tried to find from whence the gold procceded—to find a gold mine!!! To such persons, if there be any so sanguine, I will give them this information, that in streaming the moor from the south to the north, the gold, probably washed down by the river, was not found to the north of a certain line; the lode therefore must cross the valley near this line, above which no gold was found in an east and west direction.

IX.—Vegetable Remains in the Basin at Portleven.

Communicated in a letter from Rev. John Rogers, Member of the Society, to John Ayrton Paris, M.D.

A few days ago I observed, at the bottom of the basin at Portleven, and imbedded in vegetable mould, at the depth of from twenty to twenty-five feet from the level of the road, and a little above low water mark, several stumps of oaks and willows, all apparently *in situ*, with their roots extending through the mud. I think they must have been about ten feet

below the surface of the sand, which formerly occupied the site of the basin, and there must have been either a subsidence of the soil, or what seems more probable, a rise of the sea since the period of their growth; the same theory, whatever it may be, must account for them, and for the stumps of oaks, mentioned by Borlase, and which are so frequently seen in the Mount's Bay.

X.—Contributions towards a knowledge of the Geological History of Wood Tin.

By ASHHURST MAJENDIE, Esq. M.R.G.S.C.

The geological history of the *wood tin* of Cornwall is so obscure, that perhaps I may be excused in offering to the Society the few, though indecisive hints, which I have been able to procure on the subject, in the neighbourhood of the places where this substance has occurred most abundantly in *stream works.* At Trethurgy Moor, near St. Austel, a few specimens have been found of what is provincially called *toad's eye wood tin*; these consist of very minute spherical masses of wood tin, the fibres of which radiate from a centre, imbedded in a stone, composed of quartz and

coarse amorphous tourmaline, (the schorl rock of Werner) which rock abounds at Carclase and other mines in that district, forming large veins in a decomposed granite. These specimens have been traced to a certain spot, and it is conjectured, with some probability, that the vein of wood tin is not far distant. From the same moor I have seen a single specimen of *wood tin* of considerable size imbedded in the same substance as the *toad's eye* tin, so that in this instance the nature of the vein at least is known. At a mine worked about seventeen years ago in Lower Saint Colomb, called Huel Providence, I was informed by the captain that *wood tin* was found in masses a pound in weight in the *lode*, which was what is called among miners, a *flucan*, being a vein consisting of clay, in which all the *wood tin* and the rest of the tin, which was the common oxide, were found, not attached to the walls of the *lode*, but imbedded in the clay.

The wood tin of Cornwall is described in treatises on mineralogy, as occurring in small detached masses in stream works. Of the gangue nothing is known, but that sometimes a small portion of quartz is attached. Some specimens I have lately met with in the vicinity of St. Austel, afford such information as to leave little doubt respecting the geological history of this substance. One of these speci-

mens from Trethurgy Moor was a portion of a vein having the wall of granite attached. I am informed that specimens have been traced to a particular spot in the moor where they cease to occur. It is probable that the veins might, after some examination, be found *in situ*. It appears, therefore, that this variety occurs in veins of schorl rock, traversing granite like the common oxide of tin.

XI.—Notice relative to the Formation of Swimming Stone.

Amongst a great number of specimens of this substance, which have been discovered within a few years past, scarcely any have been found which have exhibited more than a skeleton of siliceous matter, except perhaps a little sulphuret of copper. The minuteness of the cells, together with the arrangement of their plates, are doubtless the causes of of its buoyancy on water. It is evident that these cells must, at some period or other, have been filled with other matter, more easily and generally soluble than silex.

I beg to exhibit to the Society a specimen which was some time since found in Pednandrae mine, near Redruth, which appears to me to contain a complete illustration of the formation of swimming stone. This specimen

seems to have been originally nothing but fluor spar, the parts of which were very loosely connected, as is evident from the fluor which still remains. It will be observed, however, that almost all the crevices throughout the mass of fluor, are filled by the matter of silex, which has been deposited there, perhaps by the passing of water through them.

On one side the fluor has been dissolved, and the siliceous matter remains just in the form in which it appears in the swimming stone.

It is well known that sulphuric acid has the power of disengaging the fluoric acid in the state of gas. Whether, therefore, this acid gas, by its action on the silex, could have produced the peculiar appearance of the swimming stone, I presume not to decide.

The mines which have produced the swimming stone in the greatest quantity, are Relistian in Gwinear, and Huel Alfred in Phillack, neither of which is now at work. In the former mine was found a still rarer substance: swimming sulphuret of copper, which I believe has not been found any where else.

XII.—*The following notice was received when the printing of this Volume was nearly completed.*

My communication on Elvan Courses (see page 96), was written nearly two years ago. There is a remark in it which intimates that the underlie of those courses is almost always in the same direction as that of the adjoining strata. Since that period I have learned that there are several elvan courses in Cornwall, (the particulars of which will probably be given in another communication to the Society), whose underlie is in a contrary direction. I shall therefore be glad, if my paper be not already printed, to alter that remark; or if it be printed, that this note should be inserted among the notices at the end of the volume now printing.

JOSEPH CARNE.

Riviere, May 2, 1818.

QUERIES

Proposed to Captains of Mines, and other persons connected with the practical part of Mining.

By JOHN HAWKINS, Esq. F.R.S. &c.

MEMBER OF THE SOCIETY.

THE following queries were put into the hands of the most intelligent captains of our mines, in the years 1791—2.

As they were drawn up for the purpose of obtaining the best information respecting the phenomena of mineral veins, which could be collected from that class of persons; it was necessary to adopt a language which they could understand, *i. e.* to make use of provincial terms that could not be easily misunderstood. It was moreover necessary to have in view all the circumstances, usually occurring in the natural history of our Cornish lodes, and those only.

I was enabled to accomplish this, by the examination of some of our most remarkable

mines during the years 1790—1. The queries, however, which I subjoin, may be regarded as the practical result of a much longer attention to the subject, begun in Saxony under the guidance and instruction of Werner, and continued in Bohemia and Hungary.

The answers which I obtained from the persons, to whom the first series had been addressed, were, upon the whole, very satisfactory; and I felt gratified by their ready compliance with my wishes.

This success encouraged me to circulate among them the second series, to which, however, I obtained answers in a few instances only. The questions comprehended in this series are, it must be confessed, more complex and difficult than the former, and the captains of our mines (who, although a very intelligent class of men, are not in the habit of expressing their observations on paper), may have felt a very natural reluctance to commit themselves. I should be sorry therefore to ascribe their silence to any other motive.

The enquiry thus interrupted, may now be resumed under much better auspices, and as the zeal which has been excited by the enlightened founder of our Society, can be directed to no object of greater importance, I am induced to lay before the Society such an arrangement of the questions which apply to the phenomena of lodes, as will very materially abridge their labour.

My associates will moreover be sensible of the convenience which results from a unity of plan in their patriotic endeavours, and will soon perceive that a mode of investigation which insensibly leads them on from the more easy and obvious phenomena, to those which are more difficult and uncommon, is the best adapted to their purpose.

But here I must beg leave to observe, that the value of their information will much depend upon the circumstances under which it is obtained. If the best practical miners are often deceived in their judgment of those numerous accidents which affect a lode, and either raise or depress the estimation of a mining adventure; how much more must an unprofessional observer be liable to error? In fact, it is not until all the phenomena of mineral veins are become familiar to the geologist, that he can feel a confidence in his own judgment, or presume to describe and account for, what must generally be investigated under so many difficulties and disadvantages.

Most fortunately for the encouragement of so interesting a pursuit, there are circumstances in the form and outline of this peninsular county which will afford much preliminary instruction. Its coasts present almost every where a natural section of the strata which compose them; and this section, whenever it approaches the mining districts, invariably lays open to view the mineral veins which abound there. The geologist

therefore may avail himself of this natural advantage, which no other country in Europe would afford him.

I have already observed, that much information was procured by means of these written questions, and my own personal observation; but much remains to be done; and a great mass of well ascertained facts must be collected, before we can draw any certain conclusions respecting the origin of mineral veins. I am of opinion, however, that when this is accomplished, we shall have gained a step of no small importance towards a knowledge of the formation of the earth, if we do not stand on the very threshold of the edifice. "Vestibulum ante ipsum primoque in limine."

To conclude, the object being so important in every sense, and the means so much within our reach, I feel confident that the attention of the Society will be more particularly directed to our *mineral veins*; and that in this department at least of geological science, their labours will be eminently successful; for it is the opinion of one who has had opportunities of visiting the mines in most parts of the continent, that Cornwall abounds more in mineral veins than any country of equal extent in Europe; that the phenomena which usually accompany them, are no where more strongly marked; and that no country affords the same facilities for observation.

QUERIES RESPECTING LODES.

FIRST SERIES.

1. What is the general direction of lodes in this parish?

2. How many feet in a fathom is their general underlie?

3. To which side do they underlie?

4. What is their average bigness?

5. What is the general direction of the cross-gossans and cross-flookans?

6. How many feet in a fathom is their general underlie?

7. On which side do they generally underlie?

8. What is their average bigness?

9. Do they generally heave the lodes?

10. If so, how far do they generally heave them?

11. Are the lodes generally heaved to the right?

12. In what cases are they not?

13. Are there any instances in this parish, of lodes started or heaved by slides, as in the Pink mine and North-downs? and in this case,

is the lode started by a gossan-slide or by a flookan-slide?

N. B. By a slide is meant, the intersection of a lode in its underlie; by a heave, the intersection of a lode in its course or run.

SECOND SERIES.

1. In computing the average bigness of the lodes, did you include the *caple* or not? If not, you are desired to state what difference this makes.

2. What are the particular circumstances of the case, in which lodes are not heaved as usual, to the right? I mean, what is the direction of the lode and cross-course so heaved, the side to which each underlies, and the degree of its underlie?

3. Is the heave greatest when the cross-course is big, or when it is small?

N. B. To avoid ambiguity, the comparison may be made between gossan and spar; courses of different breadths, and between these and flookans, which I believe are invariably small.

4. Is the heave greatest when the cross-course intersects the lode at a small angle, or when it intersects it at a great one?

5. Are the heaves usually greater or less in the *bottoms* than at *grass*? That is, does the heave occasion a difference in the underlie of the two segments of the lode; what is this difference, and what the circumstances which accompany it?

6. In the case of a heave, are the two corresponding parts of the lode at the same level, usually of an equal bigness, and filled with the same substances, or the contrary? In which latter case, you are requested to mention the most remarkable instances.

7. Do you know any instance of a lode being shattered, divided, or torn open by the intersection of a cross-course, or by a heave?

8. Do you know any instance of a lode being wholly cut off by a cross-course, so that no traces of it could be found on the opposite side?

9. Do you know any instances of the intersection of tin and copper lodes, and of heaves in consequence thereof?

10. Are there any regular courses or quarries of elvan, or any other sort of rock, in your parish, and what is their bigness, direction, and underlie?

11. Do you know any instance of such a course or quarry forming one of the walls of a lode?

12. Do you know any instance of such a course or quarry intersecting and heaving a lode? And if so, you are requested to state the circumstances.

13. Do you know any instances of great hollows found in the body or the sides of lodes?

14. Do you know of any instance of pebbles

or of fragments of killas, elvan, irestone, or growan, found in the body of a lode?

15. Do you know any instance of the two walls of a lode (the country) not corresponding at the same level; *i. e.* of their being composed of different rocks, perhaps on one side of killas, and on the other of *irestone, elvan,* or *growan*? Even the *killas* may be found to differ in hardness and colour in the two opposite walls.

An Account of Tin raised in Cornwall in the year ending with Midsummer Coinage, 1815.

	Blocks of Common Tin.	Blocks of Grain Tin.
Coined at Michaelmas Quarter, 1814 ..	3109	293
Christmas Quarter, 1814 ..	2179	767
Lady-day Quarter, 1815 ..	2962	1291
Midsummer Quarter, 1815 ..	4171	841
	12,421	3192
	3,192	
Number of Blocks....	15,613	
Number of Tons	2,500	

An Account of Tin raised in Cornwall, in the year ending with Midsummer Coinage, 1816.

	Blocks Common.	Blocks Grain.
Michaelmas Quarter, 1815.....	3176	854
Christmas Quarter, 1815.....	3980	828
Lady-day Quarter, 1816.....	4540	811
Midsummer Quarter, 1816.....	4596	771
	16,292	3264
	3,264	
Number of Blocks....	19,556	
Number of Tons	3,130	

An Account of Tin raised in Cornwall, in the year ending with Midsummer Coinage, 1817.

		Blocks.
Michaelmas Quarter,	1816	4127
Christmas Quarter,	1816	5937
Lady-day Quarter,	1817	6039
Midsummer Quarter,	1817	6834
		22,937

or about 3700 Tons.

Of this number 2037 blocks were Grain Tin, and 20,900 blocks Common Tin.

An Account of the Produce of all the Copper Mines in Cornwall, in Ore, Copper, and Money, for the year ending the 30th June, 1815.

	Tons of Ore.	Copper. Tons.	cwt.	qrs.	lbs.	£.	s.	d.
Huel Abram, Oatfield, and Crenver —	9066	742	11	3	14	63,577	7	0
Dolcoath — — —	8277	721	3	1	19	66,839	6	0
Huel Alfred — — —	8438	704	15	2	8	63,745	13	6
Crennis — — —	6873	564	11	3	1	44,944	1	0
United Mines — — —	6373	562	2	1	21	51,060	17	6
Huel Unity and Poldice — —	6732	477	8	2	27	42,103	18	0
Huel Friendship — — —	3307	276	10	0	26	24,934	14	6
Chacewater — — —	3547	224	18	1	3	18,297	1	0
Treskirby — — —	2496	202	13	1	15	17,981	16	6
Huel Damsel — — —	2549	201	5	1	26	17,415	17	0
West Huel Fortune — —	1695	191	11	3	0	17,525	13	6
Huel Fanny — — —	1740	166	9	3	5	16,159	19	0
Huel Chance — — —	1096	149	0	2	6	14,055	12	0
Huel Basset — — —	1049	129	18	1	22	12,010	15	6
Huel Neptune — — —	1479	127	19	2	14	11,256	12	0
Tincroft — — —	1161	93	14	3	7	8,580	19	0
Carried forward —	65,878	5536	16	0	18	490,490	3	0

Produce of the Copper Mines continued.

	Tons of Ore.	Copper. Tons.	cwt.	qrs.	lbs.	£.	s.	d.
Brought forward —	65,878	5536	16	0	18	490,490	3	0
Huel Gorland — — —	1648	90	12	2	21	7,047	14	0
Cook's Kitchen — — —	970	67	6	0	9	5,921	5	0
Camborn vean — — —	501	56	13	1	14	5,472	10	6
Consolidated mines — —	608	46	17	3	14	4,040	12	0
Godolphin — — —	580	44	10	2	5	3,879	7	6
North downs — — —	502	38	3	3	7	3,359	5	6
Huel Sparnon — — —	460	33	9	1	11	2,997	19	0
Pembroke — — —	342	32	19	2	13	2,719	9	0
Weeth — — —	319	31	17	2	16	3,164	13	6
Trenoweth — — —	644	31	12	3	16	2,196	11	6
Huel Ann — — —	406	27	0	1	7	2,160	5	6
Creegbraws — — —	459	26	4	0	27	2,048	12	6
Huel Spinster — — —	277	24	6	3	23	2,218	6	6
Unanimity — — —	266	22	19	1	10	1,883	7	0
Huel Towan — — —	234	21	15	3	18	2,139	15	6
Tregajorran — — —	183	20	19	1	4	1,964	14	6
Huel Clowance — — —	204	17	11	3	24	1,610	9	6
Carried forward —	74,481	6171	18	0	5	545,315	1	6

Produce of the Copper Mines continued.

	Tons of Ore.	Copper. Tons.	cwt.	qrs.	lbs.	£.	s.	d.
Brought forward —	74,481	6171	18	0	5	545,315	1	6
Huel Jewel — — —	233	15	19	3	15	1,379	10	6
Lambo — — —	133	15	14	0	15	1,414	18	6
Tresavean — — —	287	15	9	2	5	1,143	17	0
Union — — —	263	14	16	1	10	1,068	13	6
Cuddra — — —	96	12	12	0	0	1,135	4	0
St. George — — —	175	11	17	2	0	934	17	6
Botallack — — —	86	9	12	1	27	841	3	0
Huel Treasure — — —	92	7	16	1	16	646	7	0
Huel Music — — —	114	7	10	1	5	602	14	0
Huel Virgin — — —	111	7	9	3	19	594	16	6
North Sealhole — — —	78	6	13	3	4	567	7	0
Polgooth — — —	30	6	12	0	0	621	0	0
Huel Maudlin — — —	83	5	14	0	8	453	7	6
Druid — — —	38	5	7	0	11	499	11	0
West Huel Virgin — —	89	4	7	2	22	340	0	6
Huel Rock — — —	68	4	4	3	27	314	18	0
Huel Regent — — —	50	3	13	3	0	265	0	0
Carried forward —	76,507	6327	9	3	21	558,138	7	0

Produce of the Copper Mines continued.

	Tons of Ore.	Copper. Tons.	cwt.	qrs.	lbs.	£.	s.	d.
Brought forward —	76,507	6327	9	3	21	558,138	7	0
Huel Fox — — —	26	3	1	0	11	270	8	0
Huel Orphan — — —	45	2	16	1	0	211	10	0
Mellanear — — —	30	1	17	2	0	138	15	0
Huel Pink — — —	56	0	16	3	5	44	16	0
Huel Spearn — — —	5	0	11	0	0	43	2	6
Sold at the public tickettings —	76,669	6336	12	2	9	558,846	18	6
Sold by private contract from Crennis	1360	114	11	0	0	9,660	0	0
Gunnis Lake	1621	125	0	0	0	10,883	10	6
Sundry small mines	334	31	9	0	0	2,717	18	6
	79,984	6607	12	2	9	582,108	7	6

An Account of the Produce of all the Copper Mines in Cornwall in Ore, Copper, and Money, for the year ending the 30th June, 1816.

	Tons of Ore.	Copper. Tons.	cwt.	qrs.	lbs.	£.	s.	d.
Dolcoath — — —	9815	849	7	3	17	67,750	9	6
United mines — — —	8441	796	16	0	8	62,856	2	6
Huel Abram, Crenver, and Oatfield —	8049	627	7	0	26	46,341	3	6
Huel Unity and Poldice — —	6897	554	17	0	0	44,114	7	6
Crennis — — —	6479	542	7	1	18	39,774	8	0
Huel Alfred — — —	6030	499	6	1	7	39,622	0	6
Chacewater — — —	4347	303	2	3	3	21,995	2	6
Huel Friendship — — —	3619	285	6	3	23	21,391	6	6
Treskirby — — —	2911	277	1	3	20	21,256	3	6
Huel Basset — — —	2550	227	1	2	26	17,869	10	6
Huel Damsel — — —	2201	174	0	2	7	13,151	12	0
West Huel Fortune — —	1627	166	8	1	16	12,771	15	0
Huel Chance — — —	1323	156	4	0	19	12,408	2	6
Huel Fanny — — —	1506	144	7	0	14	11,803	2	6
Huel Neptune — — —	1489	128	16	0	7	9,734	18	0
Huel Gorland — — —	1542	99	14	2	15	7,335	17	6
Carried forward —	68,826	5832	6	1	2	450,177	2	0

Produce of the Copper Mines continued.

	Tons of Ore.	Copper. Tons.	cwt.	qrs.	lbs.	£.	s.	d.
Brought forward —	68,826	5832	6	1	2	450,177	2	0
Weeth — — —	799	84	12	3	11	6,906	6	0
Lambo — — —	718	64	1	1	5	5,013	10	0
Huel Clowance — — —	692	67	0	2	25	5,212	19	0
Tincroft — — —	800	59	12	1	13	4,472	12	6
Cook's Kitchen — — —	684	57	16	2	24	4,527	14	0
Huel Treasure — — —	786	57	15	0	19	3,966	5	6
Consolidated mines — —	722	55	4	3	23	4,025	14	0
Cuddra — — —	502	54	10	2	12	4,290	9	6
Pembroke — — —	536	46	3	3	18	3,256	3	6
Camborn vean — — —	491	44	15	0	15	3,637	7	6
Trenoweth — — —	700	42	3	0	5	2,839	17	0
North downs — — —	436	32	14	3	9	2,452	11	6
Godolphin — — —	542	50	4	3	6	3,956	6	6
Huel Jewel — — —	378	32	1	0	6	2,381	1	0
Tregajorran — — —	241	29	15	1	17	2,366	16	6
Druid — — —	176	22	9	0	18	1,882	11	0
Huel Spinster — — —	300	24	9	3	27	1,790	13	0
Carried forward —	78,329	6657	18	1	3	513,156	0	0

Produce of the Copper Mines continued.

	Tons of Ore.	Copper. Tons.	cwt.	qrs.	lbs.	£.	s.	d.
Brought forward —	78,329	6657	18	1	3	513,156	0	0
Tingtang — — —	176	17	0	3	16	1,303	7	0
Creegbraws — — —	238	16	7	2	12	1,171	17	6
Unanimity — — —	203	16	5	3	2	1,196	14	0
Huel Sparnon — — —	211	17	11	0	7	1,440	4	0
Huel Ann — — —	256	14	10	1	24	1,064	15	6
Union — — —	148	12	2	1	24	939	13	0
Huel Music — — —	66	12	0	3	10	947	0	6
Tresavean — — —	194	9	18	1	19	630	15	0
Botallack — — —	68	8	19	1	15	656	14	0
Cuskeys — — —	87	7	19	3	10	645	0	0
Huel Regent — — —	94	6	16	1	5	505	5	0
Herland — — —	55	6	11	1	0	505	10	0
Mellanear — — —	96	6	4	0	22	485	8	0
Sundry small mines in parcels under five tons of copper —	1121	86	15	0	27	6,353	15	0
Gunnis Lake, near the Tamar —	1100	91	0	0	0	6,620	0	0
	82,442	6988	2	1	0	537,621	18	6

An Account of the Produce of the Copper Mines of Cornwall in Ore, Copper, and Money, in the year ending the 30th June, 1817.

	Tons of Ore.	Copper. Tons.	cwt.	qrs.	lbs.	£.	s.	d.
United mines — — —	10,220	956	1	0	25	63,116	11	0
Dolcoath — — —	9807	794	8	2	2	51,486	18	0
Huel Abram, Cranver, &c. — —	9185	695	5	3	25	41,998	2	6
Huel Unity and Poldice — —	5651	508	13	2	21	33,176	4	0
Crennis — — —	5037	444	17	0	0	27,067	14	0
Chacewater — — —	4108	314	15	1	18	19,508	19	0
Treskirby — — —	2883	286	11	2	5	18,806	17	0
Huel Friendship — — —	2948	226	16	2	24	13,344	7	0
Huel Basset — — —	2314	202	14	3	2	13.096	15	6
Huel Damsel — — —	2134	180	12	1	9	11,611	4	0
Huel Neptune — — —	1292	150	14	1	24	10,147	10	6
Huel Fanny — — —	1379	130	17	1	7	8,809	9	0
Camborn vean — — —	952	126	14	2	27	9,060	3	6
Huel Chance — — —	973	107	1	3	7	6,962	18	0
Pembroke — — —	1107	97	6	0	13	6,136	17	6
Tingtang — — —	970	96	5	1	7	6,520	10	0
Carried forward —	60,960	5319	14	3	20	340,851	0	6

Produce of the Copper Mines continued.

	Tons of Ore.	Copper. Tons.	cwt.	qrs.	lbs.	£.	s.	d.
Brought forward —	60,960	5319	14	3	20	340,851	0	6
Tincroft — — —	1250	93	17	1	4	5,565	18	0
Huel Music — — —	439	91	12	3	27	6,578	16	6
Huel Gorland — — —	1351	85	1	0	7	5,353	13	0
Huel Squire, east — — —	724	79	10	1	20	5.698	15	6
Trenoweth — — —	1090	72	18	2	17	4,229	14	0
West Huel Fortune — —	663	71	13	2	0	4,545	17	0
Huel Clowance — — —	622	63	0	3	26	4,199	4	6
Cook's Kitchen — — —	698	58	8	0	27	3,738	0	0
Weeth — — —	597	57	10	1	11	3,536	4	0
Cuddra — — —	547	48	19	2	5	3,014	15	0
Huel Treasure — — —	551	46	12	2	18	2,929	14	6
Huel Alfred — — —	718	42	16	2	22	2,481	10	6
Consolidated mines — —	443	37	1	1	14	2,326	7	6
Botallack — — —	211	28	16	0	22	1,803	17	6
North downs — — —	281	22	0	0	0	1,378	7	6
Huel Jewel — — —	276	21	15	3	10	1,350	15	0
Huel Spinster — — —	219	17	15	2	12	1,148	4	0
Carried forward —	71,640	6259	6	1	10	400,730	14	6

Produce of the Copper Mines continued.

	Tons of Ore.	Copper. Tons.	cwt.	qrs.	lbs.	£.	s.	d
Brought forward —	71,640	6259	6	1	10	400,730	14	6
Lambo — — —	239	17	5	0	5	1,019	19	6
Tregajorran — — —	144	17	3	0	20	1,136	12	0
Creegbraws — — —	179	15	2	3	13	926	4	6
Huel Jubilee — — —	186	13	19	0	0	823	1	0
Godolphin — — —	159	11	11	3	27	704	6	6
Tresavean — — —	212	10	9	0	22	539	6	0
Sundry mines less than ten tons —	968	80	8	0	12	5,055	16	6
	73,727	6425	5	2	25	410,936	0	6

Quantity of copper sold at the public ticketings ..... 6425 Tons
Sold from sundry mines by private contract..... 183

Produce of Cornwall..... 6608 Tons

Quantity of Copper produced in Great Britain and Ireland in the year ending the 30th June, 1815.

	Tons.
Cornwall	6607
Devonshire	424
Anglesea	305
Other parts of North Wales and Ireland	204
	7540

Quantity of Copper produced in Great Britain and Ireland, in the year ending the 30th June, 1816.

		Tons.
Cornwall.... sold at public ticketings	6830	
by private contract	215	
		7045
Devonshire		345
Anglesea		448
North Wales, and those parts of Ireland where the ore is not smelted		271
		8109

No account has been received of the produce of the Ecton Mine in Staffordshire, nor of the Cronebane Mines in Ireland.

Quantity of Copper produced in Great Britain and Ireland, in the year ending the 30th June, 1817.

	Tons.
Cornwall	6608
Devonshire	350
Staffordshire (Duke of Devonshire's mine at Ecton Hill) about	200
Anglesea	432
Other parts of North Wales	80
Sundry small mines in Ireland, of which the ore is smelted in Wales	80
Cronebane Mines in Wicklow (no account has lately been received, but the quantity is supposed)	150
	7900

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